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Technical Specifications

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D.1. General

D.1.1 Scope of the Specifications

This section outlines the general requirements for civil works and civil works for construction of facilities to be carried out by the Contractor. Specific requirements for civil works for pipe works are given in Part E The work required under this sub-section shall include all labour, materials, equipment, remedy of deficiencies, site clearance and all other appurtenant works required to complete all civil works and facilities specified herein. Not mentioning any specific material or plant does not necessarily imply that such specific material or plant is not included in the works.

The Contractor shall, unless otherwise specified herein, supply all materials, equipment, temporary works, machinery and labour necessary to perform, maintain and complete the works.

All Civil Works, unless otherwise specified, shall comply with the provisions of this Section. The names of the manufacturers of materials proposed for incorporation in the Works, shall be furnished by the Contractor when so requested by the Engineer who shall have power to reject any parts which in his opinion are unsatisfactory or not in compliance with the Specification.

D.1.2 Standards and Rules

All design, facilities, materials and workmanship shall comply with the relevant latest ISO, EN or equivalent international and local standards and codes of practice.

Materials supplied and work performed shall comply with these standards and regulations as a minimum. If manufacturers offer material to other standards, the standards shall be equal or superior to those specified and full details of the difference shall be supplied to the Engineer.

Wherever a national specification, technical standard, building, construction and environmental regulation is more restrictive than the specific standards listed in these specifications, the national standard or regulation shall take precedence .

The designs shall be carried out in accordance with:

- EN 1990 Eurocode 0: Basis of structural design;
- EN 1991 Eurocode 1: Actions on structures ;
- EN 1992 Eurocode 2: Design of concrete structures;
- EN 1997 Eurocode 7: Geotechnical design;
- EN 1998 Eurocode 8: Design of structures for earthquake resistance

D.1.3 Scope of Works

The civil works comprise all works in connection with the construction works such as soil investigations / soil replacement, site installations, temporary works, civil structures below or above ground, reinforced concrete structures and masonry, structural steel and iron works in connection with civil and concrete structures, interior and finishing works, building equipment for installations, infrastructural and environmental works, etc.

The Contractor shall provide all the installations, temporary buildings, temporary site infrastructure and services etc., which make his site operation feasible and enable him to start, to execute and to complete the works in due time and to the satisfaction of the Engineer.

The Contractor shall be entirely responsible for the design, safety, stability and sufficiency of the works in accordance with local regulations.

D.1.4 Approval of Materials and Workmanship

The supply of all materials and items shall be subject to the prior approval of the Engineer. The Contractor shall provide such samples as the Engineer may require for approval, as well as appropriate evidence of quality and usability in order for the materials to be approved, and, when approved, the quality of materials and workmanship shall be at least equal to the approved samples.

D.1.5 Design Loads, Structural Design and Analysis

Structural design work to be prepared and submitted by the Contractor shall include all structural engineering and the pertaining shop drawings (formwork and reinforcement) for all in-situ concrete structures. Furthermore, the structural design shall include the stability analysis of the underground conditions.

All structures and parts thereof shall be designed to withstand the maximum loads from within the plant and its components, including dynamic effects where they occur. These include dead and live loads to which they are subjected including temporary and erection loads occurring during construction, earth and water pressures and all the other loads resulting from earthquakes, winds, earth, hydrostatic pressures and others. Such loads shall be clearly indicated in the design calculations. Moreover, the structural design shall be carried out to ensure the stability and durability of the structures.

Loads shall be taken as stated in Eurocode and the relevant local standard.

In his QA/QC Programme, the Contractor shall define the procedures for preparation for the approval of the structural designs. During the Final Design, detailed design calculations for each individual structure, together with general arrangement drawings, reinforcement drawings and bar schedules, are subject to the checking and approval procedures as laid down in the QA/QC Programme.

A statement explaining the principles of the design shall preface the detailed calculations and the type of analysis adopted and any design references on which the design is based.

For a concrete structure, the class into which the structure has been placed for design purposes shall be stated.

For a superstructure framework, a separate statement shall be included explaining how overall stability has been achieved and whether reliance has been made on walls, whether of brick, concrete or other material to provide stability.

All loads and structural wall sizes, including positions and sizes of any significant chases and openings shall be clearly indicated in the design calculations.

Design shall allow for the effects of ambient temperatures and temperatures of contained liquids as well as the effect of direct sunlight.

D.1.6 Special Loads

D.1.6.1 Roof and Wind Loads

Roof and wind loads shall be in accordance with local and EN standards.

D.1.6.2 Crane load

Crane loads shall generally be in accordance with the design principles as described by the Federation Européenne de la Manutention (European Materials Handling Federation, FEM) in the "Rules for the design of Hoisting Appliances.

D.1.6.3 Floor Load

Floor slabs in operating areas shall be designed for all permanent loads and other loads, which could take place during maintenance or repair work, but not less than 5 kN/m² over their total area. Maintenance walkways shall be designed for more than 2,5 kN/m².

D.1.6.4 Water load

Structures shall be designed to resist water loading due to uplift. Forces on pump wells, tanks, channels, culverts and pipes shall be calculated according to the assumption that they are empty; the factor of safety against flotation shall not be less than 1,1 for this condition.

No reliance shall be placed upon side drains or under drains to lower the natural level of ground water locally in the vicinity of structures. Where structures are constructed above the natural groundwater level and this is relied upon in the design, positive means of drainage shall be provided to prevent accidental uplift arising from leakage of contents or percolation of surface water into the backfill. In the case of structures, which are partially submerged, drainage shall be similarly provided above the designed maximum water level.

Where additional amounts of concrete beyond the normal structural design needs are introduced, for example for the purpose of gaining dead weight to counter the effects of buoyancy, any such addition to the concrete shall, as far as possible, be uniformly distributed among the substructure members.

Structures that may be water tested before backfilling shall be designed for no external pressure from water or backfill together with maximum internal water pressure.

The design of walls for tanks, wet wells and the like shall allow for accidental filling of freeboard by water to the tops of the extended walls.

D.1.7 Foundations Design

The Contractor shall carry out his own detailed foundation conditions investigation to make himself fully aware of all the subsoil conditions affecting the construction and maintenance of the plant as well as the safe bearing capacity of the foundation soil adopted in the design with no restriction to the given recommendation. The Contractor shall investigate the amount of sulphate and chlorides contained in the subsoil in order to check the necessity for providing corrosion protection for underground structures.

Suitability of materials on site for filling shall be checked and the Contractor shall carry out tests, investigations to determine the best method for utilisation of excavated materials as fill.

D.1.8 Method of Construction

All structural element containing or conveying sewage, sewage sludge, effluent or water shall be constructed in reinforced or pre-stressed concrete, including tanks, channels, culverts and chambers.

Storage tanks for process chemicals should be made of reinforced concrete with the use of sulphate-resistant cement CEM III, or with Portland cement with a coating in the form of a protective membrane as needed, or prefabricated from corrosion-resistant materials such as PVC, GRP, etc.

D.1.9 Architectural Design

Buildings intended to house process machinery as well as those intended for administrative purposes, should be made of reinforced concrete foundations, framing, floors and roofs, with infield masonry panels or prefabricated cladding.

The architecture of the surface buildings and general all visible surface structures shall present a pleasing external appearance but having clean and simple lines combined with good weathering and low maintenance properties. The appearance shall be similar to existing structures and buildings which are located at the construction site or its vicinity. Materials shall be selected for a long life, taking into account the exposed nature of the site.

The architectural design for buildings and structures exposed above finished ground level shall be submitted to the Client with the Preliminary Design for approval before commencing the final designs.

Rainwater disposal shall be provided such that no roof or overhang water runs down the face of the building. Effective drains shall be incorporated in all overhanging elements.

Buildings containing heavy and or voluminous items requiring handling by mechanical means shall be provided with doors/gates suitable for trucks. The door height shall be not less than 3 metres. Separate personnel access doors shall be provided in addition to the equipment doors.

Buildings for chemical and fuel storage shall conform to all respective safety standards requirements.

D.1.10 Rooms for Electrical System

Generally, water, sewage, drain, gas or other kinds of pipe or duct, which are not related to the room, shall not enter areas and rooms where electrical equipment is installed. The floor shall be levelled, dust-free and not slippery.

Walls between rooms for electrical systems and other rooms can be made from light concrete or other kinds of masonry. Walls and ceilings shall have surfaces, which do not cause peeling or falling particles. Walls, ceilings and floors shall be painted with dust-binding paint.

All rooms with electrical equipment shall be fire-retardant and resist fire for at least 60 minutes.

Exits from rooms with switchgear shall be provided with doors, which open outwards. The exit doors shall emerge to platforms or other rooms with an area of at least 1,5 m² and be located at the same level as the floor of the actual Switchgear rooms. From the platform or the escape areas evacuation shall be possible.

D.1.11 Thermal Performance

Heated and air conditioned buildings shall be designed to utilise minimum energy consumption. Windows shall be designed in such a way that in the summer months there will be little or no direct sunlight into the rooms. Wall and roof construction shall be designed to prevent condensation within the building elements (interstitial condensation).

D.2. Demolition and Protection of Works

D.2.1 General

Existing buildings and structures on site which the Engineer may order to be demolished or may be required to be removed for the construction of the permanent works shall be demolished to the extent necessary to construct the various units of work but at least to a depth of 1,5 meter.

The demolition of structures includes the demolishing of all kinds and grades of bricks, wooden structures, plain concrete and reinforced concrete, pipes, all requisite shoring and strutting or other supports incidental to demolition works, the removal of debris from site, final site clearance and making good of disturbed parts.

Details of the buildings and structures to be demolished by the Contractor shall be ascertained by the Contractor prior to the commencement of any demolition work during the construction of the Works and shall be to the approval of the Engineer. The Contractor shall be obliged to complete his survey in order to obtain any outstanding information

The Contractor shall, amongst other risk investigations; examine the features of the structures, and ensure whether any shock or vibration could damage surrounding executed work, fixed equipment or any existing buried services and investigate the existence of hazardous materials including - but not limited to - asbestos, PAH, PCB, etc.. In case hazardous materials are found he shall comply with requirements set forth in Section VII, c) Specifications for Project Area Environmental, Social, Health and Safety Management (ESHS), here chapter 16.

The Contractor shall be obliged, prior to the commencement of any demolition work, to disconnect all affected existing live services according to the directions and instructions of the Engineer and any relevant Statutory Authority. In this respect the Contractor shall be obliged to obtain on time all necessary permits and provide the necessary notices to all parties concerned.

The work shall be carried out in such a manner as to cause as little inconvenience as possible to the occupants of adjoining premises and the public. The debris shall be sprinkled with water to prevent dust arising. The Contractor shall provide all requisite shoring and strutting or other supports incidental to the demolition work, remove debris from site and finally clear the site and make good all parts of the work which are disturbed.

D.2.2 Permission

The Contractor shall not demolish or remove any existing buildings, structures or other objects including trees, whether indicated on the Contractor's approved shop drawings or not, without the approval of the Engineer.

Permission for demolishing existing buildings and structures shall be applied in writing to the Engineer and shall be accompanied with a demolition programme. No demolition shall take place before obtaining the Engineer's permission and the area has been provided with all necessary relevant temporary works and/or additional works which have been either requested or authorised by the Engineer.

Demolition works shall be carried out using approved methods and in accordance with any safety regulations of the local municipality and Authorities. The Contractor should note that a Building Permit might be required for demolition works.

D.2.3 Workmanship

The Contractor will submit for the Engineer's approval the methods applied for demolishing and the proposed temporary safety measures before moving equipment into the site and commencing operations. The method statement for demolition shall include the proposed method that is such that any nuisance arising from dust, noise, and vibration are kept to an acceptable level and ensure the safety of structures adjacent to those to be demolished. The use of explosives is strictly prohibited.

Underground structures shall be broken out to a depth required for removal of them. Sumps, pits, chambers and the like shall be properly cleaned out and filled with clean demolition hard-core (if required or instructed by the Engineer), excluding any wood, plastic, sheet metal, loose reinforcement steel and the like. Demolition of walls, tanks, and plates inside building to be rehabilitated will be performed with the required care, without damaging the stability of the structure.

Where required or directed by the Engineer, the existing structure will be temporary reinforced to assure the stability. The Engineer's approval shall not relieve the Contractor of any of his responsibilities under the Contract.

D.2.4 Ownership and Disposal of Demolition Materials

The Employer shall have the option of retaining ownership of any materials arising from demolition and may remove them at his own expense. In the absence of the Employer giving reasonable notice of his intention to take possession of such materials, ownership shall revert to the Contractor who shall become responsible for removal from the site and disposal.

If becoming property of the Contractor, all materials arising from the demolition and clearance of water lines, buildings, structures and other objects mentioned shall be removed from the site promptly and disposed of in a place and in a manner acceptable to the local municipality and Authorities.

D.2.5 Refilling and Finishing

All voids shall be re-filled with soil compacted to the same density as the surrounding soil and the surface shall be finished to the existing ground level and to the satisfaction of the Engineer.

Where existing sewers are connected to the new systems, the sewer downstream to the connection, which is not incorporated into the new system, shall be abandoned.

Buried pipelines to be abandoned shall be sealed with mass concrete plug of minimum length 1.0 m at either ends and between manholes. Manholes on abandoned pipelines shall be demolished to a depth of 1.5 m below final ground level and the void filled with hard core or other approved fill material and surface reinstated to a finish similar to that of the surrounding area.

D.2.6 Protection of Existing Objects

Existing objects, including buildings, structures, fences and other objects including trees which are situated on or near the site(s) and which shall be maintained, shall be protected from damages during implementation of works.

The Contractor shall:

- Protect benchmarks, existing structures, fences, roads, sidewalks, paving and curbs against damage from equipment and vehicular traffic;
- Protect aerial, surface, or underground utility lines or appurtenances, which are to remain;
- Repair any damage caused during the works to facilities which shall be maintained.

Any property situated in close proximity to the Works shall be protected against any damage that could be caused by vehicles, subsidence, vibration, etc. The Contractor shall either repair any damage caused or the Contractor shall pay for the works to be repaired to the condition of the property prior to damage and to the satisfaction of the Engineer.

Construction works and trench excavation at utilities, along existing supporting walls, at dams and embankments shall be executed under strict avoidance of settlements. The contractor has to apply a suitable method for pit/trench sheeting and bracing with low vibration and low concussion.

D.3. Clearing and Grubbing

D.3.1 Clearance of Sites

All areas of the site, marked on drawings for clearance or from which material has to be excavated or upon which fillings have to be deposited shall be levelled and be cleared from all debris, all obstructions and all vegetation except trees marked for conservation. Excess materials obtained from site clearance shall be disposed of the site at locations proposed by the Contractor and approved by the Engineer.

Site clearance shall also include the inspection of the construction site, the record of existing status by photo documentation and levelling.

The Contractor shall clear the reservation widths for pipelines, road facilities and the sites of structures free of all vegetation, trees up to 0.5 m girth measured 1.0 m above ground level, and all superficial obstacles such as road surfaces, kerbs, bricks, debris, rubbish and/or other objectionable matter.

When ordered by the Engineer, the Contractor shall also clear the sites of trees over 0.5 m girth, buildings and/or structures. The supervision team in close cooperation with the International Occupational Health & Safety Expert (ESHS) will coordinate the instruction closely with relevant department as well as local authorities.

The extent of Contractor's clearing and grubbing operations shall be the minimum practicable necessary for the construction of the Works.

D.3.2 Removal and Replacement of Trees and Hedges

Where directed by the Engineer, trees shall be uprooted or cut down as near to subsoil level as possible. The supervision team in close cooperation with the International Occupational Health & Safety Expert (ESHS) will coordinate the instruction closely with relevant department as well as local authorities. Branches and foliage shall be disposed of the site at locations proposed by the Contractor and approved by the Engineer. Stumps or roots whether existing or remaining after the felling of trees shall, where directed by the Engineer, be grubbed out and disposed of the site at locations proposed by the Contractor and approved by the Engineer. The resulting hole shall be filled with approved material and well compacted.

Any damage to the canopy of trees of girth greater than 900 mm shall be treated by an approved tree surgeon as promptly as possible after the damage occurring or on any instruction from the Engineer. Replacement trees and hedges shall be planted in the appropriate season and shall be replaced by the Contractor.

D.3.3 Protections

Trees and/or other vegetation designated on the Contractor's approved shop drawings or directed by the Engineer for preservation shall be kept free from clearing operation and be protected from damages during execution of the Works.

D.3.4 Road Furniture

The Contractor shall re-install any road furniture (such as street lighting, traffic sign, traffic lights as well as part of the underground installations) that has to be removed during the progress of the Works.

Installation of the road furniture shall take place at its original location, in a condition at least equal to that prior to removal and as soon as practicable after completion of construction works at a particular location.

D.3.5 Disposals

Trunks arising from the clearing and grubbing operations shall remain the property of the Employer unless the Employer transfers this right to the Contractor. The trunks shall be deposited in a warehouse at a location proposed by the Contractor and approved by the Engineer.

Other remnants of vegetation, including trees, stumps and roots, shall be removed from the site by the Contractor unless otherwise directed by the Engineer.

D.3.6 Blasting

Not applicable.

D.3.7 Notice of Commencement

The Contractor shall provide the Engineer and the competent local authorities with a written notice of his intention to commence the clearing and grubbing (and/or blasting operations if applicable). Notice of commencement of works shall be submitted 7 days before the date of commencement of works. The works shall not be commenced until written approval has been received from the Engineer.

The Contractor shall ensure that all clearing, grubbing and blasting are carried out far enough in advance of other construction operations within the relevant areas in order to avoid delays.

D.4. Earth Works

D.4.1 General

D.4.1.1 Works included

Earth Works as specified hereunder shall include staking out the route, the location of underground installations, the preparation of the site including protective fencing, excavation including strutting, sheeting, bracing and protection of slopes, disposal of excavated materials off site, backfilling including delivery of backfill material and site clearance including disposal of surplus material.

D.4.1.2 Standards

The Contractor shall carry out the works or provide materials in accordance with the appropriate local or approved similar international standards (ISO, EN and others), provided their requirements are superior or equivalent to the quality described by the standards cited in the Specifications. These include, but are not limited to, the following:

- ISO 14688-1 Geotechnical investigation and testing - Identification and classification of soil - Part 1: Identification and description
- ISO 14688-2 Geotechnical investigation and testing - Identification and classification of soil - Part 2: Principles for a classification
- ISO 14689 Geotechnical investigation and testing - Identification, description and classification of rock
- ISO 17892 Geotechnical investigation and testing - Laboratory testing of soil - Part 1 to 11.
- ISO 22475 Geotechnical investigation and testing — Sampling methods and groundwater measurements - Part 1 to 3
- ISO 22476 Geotechnical investigation and testing - Field testing — Part 1 to 15

- ISO 22477 Geotechnical investigation and testing - Testing of geotechnical structures
- EN 1610 Construction and testing drains and sewers
- DIN 4124 Building pits and trenches
- DIN 18300 General technical codes for earthworks
- DIN 18303 General technical codes for excavation lining.

D.4.1.3 Classification of Soils

The following terms shall apply to Specification Clauses in which reference is made to the excavated materials in accordance to international approved Standards mentioned above (DIN 18300, ISO 14688 Part 1 and 2) and local soil categorization (1-7 category of soil).

Topsoil means any surface material suitable for use in soiling areas to be grassed or cultivated (Class 1, DIN 18300).

Subsoil any material other than topsoil and rock shall be classified as “subsoil“ (Class 2-6, DIN 18300).

Rock is defined as material occurring in solid un-weathered banks or layers which, in the opinion of the Engineer, can only be removed by blasting, percussion drilling, wedging or splitting. Boulders exceeding 1 m³ in volume shall be classified as “rock“ (Class 7, DIN 18300).

D.4.1.4 Excavation Methods

The Contractor shall prepare a method statement of his proposal for earthworks operation for each particular part of the Works to be constructed at any one time, detailing the location, programme of excavation, temporary substructure and planking, placing and handling of the spoil, and ground stabilisation.

The Contractor shall submit for the Engineer’s approval his proposed method statement at least 14 days before his intended date to commence earthworks on each particular part of the Works.

The following terms shall apply to Specification Clauses in which reference is made to excavations:

Normal (surface)Excavation means excavation in open cut (excluding trench excavation) down to levels specified on drawings or otherwise as being the general levels after completion or excavation other than incidental excavation.

Trench Excavation means excavation to levels and limits specified on drawings or otherwise of trenches in which pipes or the like are to be laid.

Incidental Excavation means excavation in small quantities below or outside the limits of normal excavation and trench excavation but excluding excess excavation.

General Excavation means excavation, whether normal or incidental, required for structures, roadwork and borrows areas.

Excess Excavation means excavation outside the limits specified for normal, trench or incidental excavation. Excess excavation shall not qualify for any extra payment.

D.4.1.5 Backfill Materials

The following terms shall apply to Specification Clauses in which reference is made to backfilling of excavations:

Unsuitable Material means material not suitable for backfilling including materials from swamps, organic and perishable materials, clay and soils with high plasticity indices such as liquid limit (LL) > 80 and plasticity index (PI) > 55.

Rock Fill shall consist of hard un-weathered material of suitable size for deposition and compaction and may comprise broken stone, hard brick, concrete or other hard inert material.

Selected Fill for backfilling trenches and foundations shall comprise well graded readily compactable material free from roots, vegetable matter, building rubbish and clay lumps.

D.4.1.6 Notice of Commencement

The Contractor shall give to the Engineer and competent administrative bodies at least 7 days written notice of his intention to commence earthworks on any part of site and shall furnish the Engineer with all ground levels, site photographs showing the existing conditions and levels and other particulars he may require for the purpose of carrying out measurements.

Earthworks shall not be commenced until written approval has been received by the Contractor from the Engineer.

D.4.1.7 Stripping of Surface Layer of Soil

Where ordered by the Engineer or defined by the project, the topsoil shall be stripped from the whole or part of the site to a depth of 30 cm or to such other depths as indicated in the Contract Documents or such other depths and over such areas as the Engineer may direct, and set aside for reuse as a separate operation prior to any further excavation which may be required.

The works include excavation, loading, transport from the construction site and storage of soil in stable and well-drained piles in the area outside the construction site or in the area of the construction site where construction works are performed, if there are conditions for that.

Topsoil shall include any surface material capable of supporting vegetation and suitable for use in areas to be grassed or cultivated .

The Contractor shall not dispose of surplus topsoil without the written permission of the Engineer.

D.4.2 Excavation

The Contractor shall examine the site and familiarise himself with the nature of ground, the excavation methods to be applied and physical obstructions that may affect the work. The use of explosives will not be permitted.

The Contractor shall not execute any excavation without having the Engineer's prior approval to the methods which he proposes to employ. The Contractor shall not modify such methods thereafter without the Engineer's consent.

D.4.2.1 General Excavation

General excavation, whether normal, mass or incidental excavation, required for structures and roadwork shall be carried out to the grade of the bottom of the structure.

General excavation will be carried out after site clearance and the stripping of topsoil.

In accordance with the drawings, the Contractor shall indicate the boundaries of excavations to be made for the construction of the individual structures (boundaries of the expropriation area).

The prices quoted for general excavation shall be fully inclusive and contain all incidental works as:

- Excavation of any type of ground, including rock, which includes manual excavation, i.e. in accordance with the type of excavation and categorisation of soil according to the bill of quantities; whether this excavation has to be made by hand or by machine;
- Location, maintaining and reinstatement of existing services, where required;
- Supporting excavations and temporary support of the sides of excavations (obligatory substructure and excavation of trenches at depths ≥ 1.25 m);

- Keeping the excavation free from surface and ground water;
- Trimming, compacting and protecting of formation levels;
- Any additional excavation to accommodate temporary supports and all working space to carry out the work;
- Disposal of excavated material whether it shall be reused for backfilling or removed as surplus material off site, including formation of all temporary spoil heaps and all double handling necessary;
- All works related to pipe laying in parallel or crossing existing cables and pipe.
- Protection of the works and all additional measures necessary to ensure that the excavations are maintained in a safe and workmanlike manner.

For the removal of materials from existing surfaces and underground structures, the calculation and payment is done separately, unless stated in the cost estimate. Excavation shall be carried out in a safe manner to suitable lengths, widths, depths and profiles required for the construction of the works shown in the Contractor's approved shop drawings or to such other dimensions determined by the Engineer. Excavations in an open cut, if defined by the design, should have stable slopes. Excavations in an open cut made by the Contractor on his own initiative shall not be charged separately.

The area excavated to levels lower than the designed levels approved by the Engineer prior to commencement of work shall be back-filled to the approved level with stable gravel material to the Engineer's satisfactions.

Every precaution shall be taken by the Contractor to prevent slips or collapse of the trench during the excavations. In the event of slips or falls occurring, or in the event of excavation being made in excess of the minimum necessary or practicable for the construction of the Works, the voids so formed shall be filled. In all cases where the voids so formed when backfilled would provide support for the permanent Works or adjacent structures and services then such voids shall be filled solid with concrete of strength class $\geq C 8/10$ at the Contractor's expense. In all other cases the voids shall be packed with selected excavated material or approved trench filling material (quality gravel material) and thoroughly compacted to the Engineer's approval.

D.4.2.2 Trench Excavation

Trench excavations shall be carried out in accordance with EN 1610.

Trench Walls

Trench excavations for pipes and interconnections shall be open-cut trenches (i.e. with vertical walls). Shoring shall be implemented in accordance with section D.4.2.7. Excavation with sloping sidewall shall be subject to the approval of the Engineer. In this case, there shall be no extra payment for all related additional earthworks.

Trench Width

The trench width is defined as the width between the trench walls or between the shoring walls in case of shoring.

The trench width shall be deemed sufficient to permit the pipes to be laid and jointed properly and to place and compact the backfill as specified.

Minimum trench width depending on the trench depth as per EN 1610:

Trench depth	Minimum trench width in m
< 1.0 m	No minimum specified
≥ 1.00 m and ≤ 1.75 m	0.80 m
> 1.75 m and ≤ 4.00 m	0.90 m
> 4.00 m	1.00 m

Minimum trench width depending on the pipe outer diameter as per EN 1610 in case of circular pipes and shored trenches:

OD in mm	Minimum trench width in m
≤ 225	OD + 0.40
> 225 and ≤ 350	OD + 0.50
> 350 and ≤ 700	OD + 0.70
> 700 and ≤ 1,200	OD + 0.85
> 1,200	OD + 1.00

In case of multiple and parallel pipe laying, distance between pipes shall be sufficient to allow for reaching the compaction targets. Other criteria shall also be considered as deemed required by the Engineer.

In the event of any trench for pipelines exceeding the maximum allowable widths as specified, the Engineer will order the restoration of the trench width or the use of an alternative bedding material or such other remedial action as in his opinion is necessary. The Contractor shall then carry out the measures so ordered by the Engineer and shall have no claim against the Employer for any additional costs resulting from such instructions.

Trench Depth and Bedding

The trench shall be excavated to such depths as necessary to permit placing pipe bedding material or concrete encasement as required and to allow the pipe to be laid at the required elevations, slopes and depths. Trench bottoms shall be cleared of projections such as rocks stones roots and the like. All pipes, sewers and cables shall be laid in trenches excavated in undisturbed soil.

Trench bedding shall be carried out in accordance to Section D.4.4.9.

Bridging obstacles

There shall be additional calculation and payment only for bridging of rivers, streams, channel or canal of more than 1.0 meter width, unless such cases are defined by the bill of quantities. The width is defined as the bottom width at the bridging between axis of pipe and axis of rivers, streams, channel or canal.

D.4.2.3 Further and Excess Excavation

When the specified levels or limits of excavation are reached and approved by the Engineer, he will inspect the subsoil exposed and may, if he considers any part of the subsoil unsuitable, direct the Contractor to excavate further. Such further excavation shall be refilled to the specified levels or limits with approved imported material or concrete class C 8/10.

Any excess excavation outside the specified “payment limits” and any further excavation which has not been ordered by the Engineer shall be held to be excess excavation which will not be paid for.

The Contractor will not receive payment for the excavation or backfilling of over break, or measures necessary as a consequence of such over break except otherwise approved by the Engineer. Over break means an excavation carried out outside the designated lines.

The Contractor shall remove from the Site all material resulting from excess excavation and shall make good the same with such kind of fill material or concrete as may be reasonably required by the Engineer having regard to the circumstances.

D.4.2.4 Keeping Excavations free from Water

The Contractor shall keep all excavations free from water and sewage, whether caused by floods, storms or otherwise, so as to construct the works in dry conditions.

The Contractor shall keep infiltrating or accumulated water at a level lower than the bottom of the permanent work for such a period as required by the provisions of the Specification and the Contractor's method of construction.

The mode of drainage proposed by the Contractor is subject to the approval of the Engineer. Any sub-drainage below the permanent works shall, if left in place, be sealed with concrete or other approved material. Sub-drains underneath permanent concrete structures shall be covered with waterproof membranes.

D.4.2.5 Trial Excavations

The Engineer may direct that trial excavations shall be excavated well ahead of excavation to such depths as he shall order to determine the layers and substructure of existing works/structures.

The Contractor shall arrange for the refilling and reinstatement of trial excavations to be carried out immediately after the required information is obtained. The reinstatement of the surfaces of trial excavations shall be carried out to the approval of the Engineer.

D.4.2.6 Supporting Excavations

The Contractor shall support the sides and the ends of all excavations to prevent any fall or run from any portion of the ground outside the excavation and to prevent settlement or damage to structures adjacent to the excavation.

The Contractor shall provide, install and maintain all materials and equipment necessary to provide such support.

If, for any reason, any portion of the bottom, sides and ends of any excavation shall give way, the Contractor shall take all necessary remedial measures including the excavation and removal of all the subsoil thereby disturbed at both inside and outside the nominal limits of excavations. The Contractor will stop the works until the Engineer inspects them. The work will not be proceeding until the Engineer has approved a solution. The contractor will perform the earthworks at his own cost if the slides are caused by him.

Where the Contractor proposes to perform excavations with sloping faces and without shoring, the excavated faces shall be to stable slopes and heights. Full details of the execution shall be submitted to the Engineer for prior approval.

D.4.2.7 Trench Shoring and Planking

Trench Excavation – Shoring and Planking

Shoring and planking are mandatory for trenches with depths of more than 1.25 m.

For lower depths, depending on specific factors, such as the soil type, rain, etc., the Engineer shall decide during excavation works whether shoring is also required or not.

During excavation works without shoring, if slipping or collapsing of the trench walls involve a health risk, the Contractor shall immediately suspend the works and inform the Engineer of the occurrence.

Other Excavations - Shoring

In its methods of statement, the Contractor shall indicate where and how shoring is to be implemented. The Engineer shall decide whether shoring is also required or not. During excavation works, depending on specific factors, such as the soil type, rain, etc., the Engineer shall decide whether shoring is also required or not for depths less than 1.25 m.

During excavation works without shoring, if slipping or collapsing of the trench walls involve a health risk, the Contractor shall immediately suspend the works and inform the Engineer of the occurrence.

Shoring Method

The method of shoring to be used is specified in the bill of quantities (steel panels with supports/struts). The Contractor will be fully responsible for the stability and the effectiveness of the shoring. All costs for shoring shall be included in the excavation rates and prices offered.

D.4.2.8 Existing Cables and Pipes

The Contractor shall take all steps necessary to find, protect and safeguard any drains, pipes, cables and similar services encountered, already installed or to be installed, for the duration of the Contract in order to keep them in good working condition. Should the services become damaged during the course of the works, then the Contractor shall be responsible for liaising with the responsible utility companies or organizations and arranging for the repair of that service and bear all costs associated with the repair of the service.

Information as may be given in the Contract in relation to the present condition and character of the existing structures, roadways, embankments and the like and in relation to the dimensions of various parts of the existing structures, the position, extent and particulars of drains, pipes, cables and the like, is given without guarantee of accuracy and the Employer will not be liable for any discrepancy therein.

The absence of such information shall not relieve the Contractor of this liability for the cost of any repair work necessitated by damage caused by him to such mains and services in the course of his work and for the cost of all losses arising from their disruption.

The Contractor shall obtain all available information, assistance, full permission and approval of all relevant utility companies or organizations regarding the positions and/or relocation of mains and services, serving notices of intent to start work as may be necessary in accordance with all the local laws and regulations. He shall make this information available to the Engineer as soon as he obtains it. He shall agree with the Engineer any trial excavations, which may be necessary to confirm or establish these locations. All costs of excavations shall be deemed to be included in the Contract. All relocating works shall be carried out two weeks in advance of execution of the relevant work.

Any temporary or permanent diversion and/or relocation of mains and services shall only be permitted after agreement with the appropriate utility companies or organizations and the approval of the Engineer.

There shall be no extra payment for pipe laying works in parallel to or crossing or cables and pipes from other utilities.

During excavations, if unknown cables/pipes are discovered or if cables/pipes are not located where foreseen, the contractor shall immediately suspend the works and inform the Engineer.

D.4.2.9 Tests on Ground Water

During the course of the excavation work the Engineer will require samples of the ground water to be taken for testing to ascertain the presence of harmful substances.

The tests shall be performed in a suitable laboratory before starting any concrete work. The results concerning adverse effects on concrete shall be evaluated according to ISO 22475.

D.4.2.10 Disposal of excavated Material

All material obtained from the excavation (surplus material or material not approved by the Engineer for reuse) shall become the property of the Contractor.

The Contractor shall dispose such material off-Site at locations to be proposed by the Contractor and to be approved by the relevant authorities.

Storage on site

Excavated material shall be stored at the Site in any of the following ways:

- Transporting and placing in temporary stockpiles and backfilling to excavations including any double handling/transfer of materials; or
- Transporting and placing of approved materials in permanent stockpiles, including the shaping and drainage of such tips; or
- Transporting of selected excavated materials to locations within the site for embankments and filling around structures including organised unloading for spreading and compaction.

Stockpiles on site

Only such materials approved by the Engineer shall be placed in the various stockpiles. No tree trunks, stumps, roots, foliage or rubbish of any kind shall be placed in stockpiles.

Temporary stockpiles to store excavated materials shall be arranged by the Contractor. Such stockpiles shall be shaped as to maintain stability and good drainage at all times. Topsoil stripped from the pipeline route shall be disposed of in separate stockpiles for later use in reinstatement and landscaping.

D.4.3 Geotextiles

D.4.3.1 Standards

The Contractor shall carry out the works described in accordance with the appropriate standards or equivalent local or international standards. Applicable standards for the material shall be, but not be limited to the following:

- ISO 10319 Tensile strength (wide width)
- ISO 10320 Identification of geotextiles at construction site
- ISO 10321 Tensile test on seams and joints by wide width method
- ISO 10722 Damage to geotextiles during installation in grained material
- ISO 11058 Water Flow (normal to plane)
- ISO 12236 Static puncture strength (CBR)
- ISO 12956 Characteristic opening size
- ISO 12957 Friction values
- ISO 12958 Water flow capacity (in plane)
- ISO 12960 Resistance against liquids
- ISO 13427 Abrasion test
- ISO 13431 Tensile creep test
- ISO 13437 Sampling and testing of geotextiles at construction site
- ISO 13438 Resistance against oxidation

D.4.3.2 Application

The applications of geotextile fabrics are divided into the following three main classes:

Drainage: under all rubble rip-rap, including cyclopean stone and under gabions; wrapped around drains, pipe joints, and edge-drains; filter behind walls, etc.;

Erosion Control: silt fence and staked silt barrier;

Stabilisation: separator between embankment and soft subsoil, reinforcement and pipe bedding.

D.4.3.3 Material Requirements

The geotextile shall be the type appropriate for the intended use. The geotextile fabric shall be a woven or non-woven fabric consisting of long-chain polymeric filaments or yarns such as polypropylene, polyethylene, polyester, polyamides or polyvinyl chloride formed into a stable network such that the filaments or yarns retain their relative position to each other. The base plastic shall contain stabilisers and/or inhibitors to make the filaments resistant to deterioration due to ultra-violet light (except for subsurface and stabilisation classification), heat exposure and potential chemically damaging environment. The fabric shall be free of any treatment which may significantly alter its physical properties. The edges of the fabric shall be selvaged or otherwise finished to prevent the outer yarn from pulling away from the fabric.

Synthetic filter fabric used for reinforcing grades (in water environments under block or rock covers) shall conform to the following specifications:

The Contractor shall furnish two certified copies of a test report from the manufacturer certifying that the geotextile to be incorporated into the completed project meets the requirements of this Specification. The certified test reports shall be attested to be a person having legal authority to bind the manufacturing company. The Contractor shall also furnish two 100 x 100 cm samples of the geotextile determine product quality and any onsite testing. In addition, the manufacturer shall maintain test records as required by this Specification. These records shall be made available to the Engineer on request.

D.4.3.4 Execution and Workmanship

The fabric shall be wrapped in a protective covering which is sufficient to protect it from sunlight, dirt, and other debris during shipment and storage.

After placement, the geotextile shall not be left uncovered for more than 2 weeks.

Traffic or construction equipment will not be permitted directly on the geotextile.

Geotextile which becomes torn or damaged shall be replaced or patched. The patch shall extend 1 m beyond the perimeter of the tear or damage.

Overlaps shall be as specified by the manufacturer or as directed by the Engineer. In order to reduce overlaps, the geotextile fabric may be sewn together. Seams of the fabric shall be sewn with thread meeting the chemical requirements and minimum seam strength requirements given for the fabric and application. Sewn seams shall be lapped a minimum of 10 cm and double sewn.

Non-sewn seams shall have a minimum overlap of 50 cm except where placed under water where the overlap shall be a minimum of 100 cm.

All seams shall be subject to the approval of the Engineer.

The geotextile shall be placed and anchored on a prepared surface approved by the Engineer. The geotextile shall be laid loosely so that placement of the overlying materials will not stretch or tear the geotextile. Where geotextile is placed above water, the backfill placement shall begin at the toe and proceed up the slope.

Where geotextile is placed under water, the long dimension shall be placed parallel to the direction of flow. Successive geotextile sheets shall be overlapped in such a manner that the upstream sheet is placed over the downstream sheet. As the geotextile is placed under water, the backfill material shall be placed on it to the required thickness. The geotextile placement shall not progress more than 15 m ahead of the backfill placement.

Rip-rap, stone filling (heavy) or stone filling (medium) shall not be dropped onto the geotextile from a height greater than 0.3 m. Slope protection and smaller sizes of stone filling shall not be dropped onto the geotextile from a height exceeding 1 m.

If the above conditions cannot be met, a protective layer shall be placed on top of the geotextile (i.e. wire mesh, steel wire fabric used for concrete reinforcement, etc.)

The surface upon which the geotextile is to be placed shall be within reasonable conformity to the proposed grade. The geotextile shall be laid loosely so that placement of the overlying material will not stretch or tear the geotextile. The overlying course shall be placed in one lift and compacted as approved by the Engineer.

The geotextile shall be placed to conform loosely to the shape of the trench.

After placing the filter material, the geotextile shall be folded over the top of the filter material to produce a minimum overlap of 30 cm. The geotextile shall then be covered with the subsequent course.

D.4.4 Backfilling

D.4.4.1 Materials

Backfill material around and above the top of the pipe

The selection of backfill material is subject to the approval of the Engineer. Unless otherwise specified, the backfill material should be selected and / or crushed so that the maximum grain size has a continuous gradation that allows easy compaction. For backfilling the pipe (around and above the pipe) the maximum grain size shall not exceed 32 mm.

Fill material shall be free of organic, soluble or other deleterious materials.

Should the material selected as backfill become unacceptable to the Engineer for any reason including exposure to weather conditions, contamination and segregation during the progress of the Works, the Contractor shall remove such damaged, softened or segregated material and replace it by fresh approved material.

Pipe Sand Bedding

Any kind of pipes and cables shall be laid on and embedded in compacted bed of sand or approved excavated material in accordance with EN 1610. Sand and/or approved backfilling materials from different sources of supply shall not be mixed or stored in the same pile nor used alternately in the same class of construction without the permission of the Engineer.

Pipe Concrete Bedding

Laying pipes on a concrete bed (reinforced concrete strips) shall be done upon constructing a reinforced concrete slab. Slabs should be constructed with a designed slope for the pipeline for subsequent laying of the pipe after the concrete has dried. Detailed descriptions and illustration of reinforced concrete beds are defined by the design.

D.4.4.2 Graded Aggregates

Graded aggregates shall be used for the backfill of the top of trenches below paved areas. Except where otherwise specified that aggregate shall have the following gradation:

Sieve size (mm):	37.5	25	19	4.75	2.0	0.425	0.075
Per cent passing by weight:	100	60-100	55-85	35-60	25-50	15-30	8-15

D.4.4.3 Drainage Fill and Filter Materials

Free drainage fill and filter material shall be formed of hard durable grain and shall be free from clay, silt, soluble or organic matter. The particle size distribution shall be in accordance to the filter rules.

The Contractor shall provide for free drainage materials from approved sources. The Contractor may use material from excavation, provided it is suitable and processed in compliance with the specification of free drainage material.

D.4.4.4 Rip Rap

Riprap material shall be made of solid and stable stone material, sound, un-weathered and with low water absorption capacity in order to avoid cracking, bursting and dripping as a result of weather influences.

The rock shall mainly consist of large pieces with lateral lengths from 150 to 400 mm and smaller parts to secure the boulders against sliding and to provide stability to the fill structure. The distribution of the size of the riprap material should be:

- 150 – 225 mm: 20% in weight;
- 225 – 325 mm: 60% in weight;
- 325 – 400 mm: 20% in weight.

The density of riprap material shall be not less than 2.2 t/m³ (solid volume without voids) and each piece of riprap shall have its greatest dimension not larger than twice its least dimension.

The material delivered shall be dumped and graded off to a uniform surface up the lines and grades shown on the Contractor's approved shop drawings. No pockets of rocks and clusters of large blocks will be permitted.

The Contractor shall submit full details of the proposed source, certified test results and samples to the approval of the Engineer.

D.4.4.5 Stone Pitching

The material used in stone pitching shall be obtained by the Contractor from sources approved by the Engineer.

The stone shall be sound, persistent, durable and hard. It shall be free from laminations, weak cleavages and undesirable weathering and shall be of such properties that it will not disintegrate from the action of air, water or in handling and placing.

The dimensions of stones shall range between 200 and 400 mm. The minimum plane dimensions shall be of less than two thirds of the maximum plane dimension for each stone. The density of stones shall be not less than 2.2 t/m³ (solid volume without voids).

The stones shall be roughly dressed so that they fit reasonably close together. They shall be laid to a true and even surface, the spaces between the stones being clinched with spalls.

D.4.4.6 Reuse of excavated Material

Where, in the opinion of the Engineer, excavated materials are not suitable for refill without resorting to sieving or other special means, the Engineer may instruct the Contractor:

- to sieve out stones as may be necessary to meet gradation requirements;
- to transport suitable materials from trench excavation at distances exceeding 200 m from the section to be backfilled (overhaul); or
- to import material from suitable borrow pits to the section to be backfilled.

D.4.4.7 General Backfill

Backfilling materials and methods are generally subject to the approval of the Engineer. The approved materials shall be placed in layers, not exceeding 200 mm in depth before compaction and shall be well compacted as specified in the following:

- The layers of fill material shall be placed in such a manner as to maintain adequate drainage and to prevent accumulation of water.
- The timing and rate of placing of fill material around or upon any completed or partially completed structure shall be arranged in such a way that no part of the works is overstressed, weakened, damaged or otherwise endangered.
- Around structures the material shall be placed as to exert a uniform pressure and each layer shall be placed with a fall to prevent the accumulation of water.
- Where necessary, the moisture content of the backfill has to be adjusted to an optimum either by drying out or by adding water. After such treatment the backfill shall be thoroughly mixed until the moisture content is uniform.
- Placing the backfilling, due allowance for any settlement that may occur before the end of the Defects Notification Period shall be made. Where necessary, the Contractor shall at the end of the Defects Notification Period remove any excess material or make up any deficiency of backfilling to specified levels.

D.4.4.8 Backfilling around completed structures

The Contractor shall start backfilling only after the walls, floors and slabs of structures have been completed and have attained their full strength. Backfill around the walls of tanks and reservoirs shall not commence before successful completion and testing and after having the Engineer's approval.

The layers of backfill material shall be placed in such a manner as to maintain adequate drainage and to prevent accumulation of water. The material shall be placed with particular care for insulation and watertight coatings and all other protective or conserving surfaces and as to exert a uniform pressure around the walls of a structure and each layer shall be placed with a fall to prevent the accumulation of water.

Special attention shall be paid to the compaction of material laid immediately adjacent to concrete walls as to ensure that the material is well compacted. Hand operated vibrating plate compactors, vibro-tampers or power rammers shall be used. The compacting shall be carried out in such a way as to avoid in any case direct contact of the compacting machinery and the building.

Only the stone embankment shall be used for backfilling around the completed structures that are in the immediate vicinity of the roads. For structures that are out of traffic or other loads, backfilling shall be done with excavated material subject to prior approval by the Engineer.

In other cases vibrating compactors or pneumatic tyre rollers of types approved by the Engineer may be used for compaction.

D.4.4.9 Embedding of Pipes

Laying method

Trench bedding for laying pipes shall be in accordance with EN 1610, i.e. shall be made with stone material of selected fractions and according to the requirements of the pipe manufacturer.

Backfilling around and above the pipe in a layer of 30 cm above the top of the pipe shall be done with the same material as for the bedding. The Contractor shall submit for approval a method of statement for all representative typical cases, in accordance with the static calculation of the pipe according to EN 1295-1 or equivalent standard.

Embedding of pipes and cables includes for the supply of bedding material, preparation of the bed, placing of embedding layers (not more than 0.1 m compacted thickness) and compaction either by hand or with appropriate machines to the specified density below and around the pipes. The embedding works shall be carried out in compliance with EN 1610.

The bedding material for plastic pipes (GRP, HDPE, PP, PVC) shall be in accordance with the pipe manufacturers requirements.

The bedding material for concrete and steel pipes shall consist of sand-gravel, graded 0/25 mm.

The bedding material for cable conduits and cables shall consist of sand, graded 0/2 mm.

Approval of embedding

Formal approval of pipe laying and backfilling shall be obtained from the Engineer prior to the testing of pipes.

D.4.4.10 Main Backfill of Trenches

Backfilling of trenches shall be carried out in accordance with EN 1610.

From the top of the bedding layer above the laid pipe up to the finished ground level, the trench shall be backfilled with approved selected material, compacted by mechanical methods approved by the Engineer in layers with a thickness of not more than 150-200 mm (depend on the material and selected compacting method).

Each layer shall be compacted separately. Compaction shall be not less than 95 % modified Proctor density. Where necessary, the Contractor shall adjust the moisture content of the refill material to assist the compaction either by drying out or by sprinkling with water.

The Contractor shall provide the required number of vibratory compactors or other compaction equipment subject to the approval of the Engineer and sufficient water on site for moistening.

The Contractor shall, when placing the backfill, make due allowance for any settlement that may occur before the end of Defects Notification Period. Where necessary, the Contractor shall at the end of this period remove any excess material or make up any deficiency of backfilling to specified levels.

In the event that excavated material is insufficient or unsuitable for backfilling, the Contractor shall use imported fill material from approved borrow pits.

Where directed by the Engineer, trench excavations shall be backfilled with concrete, class C 8/10. Likewise, the Contractor shall use cement stabilised backfill where directed by the Engineer.

D.4.4.11 Tolerances for filling

The fill shall be placed and compacted to a tolerance of – 10 mm / + 15 mm for a final surface. Where further works will be carried out above the fill the tolerance shall be – 25 mm / + 0 mm.

D.4.4.12 Control and testing of the fill

Control tests with a dynamic plate shall be carried out by members of the Contractor's staff competent to perform the required tests. Final tests shall be with a static plate and shall be carried out by an authorised institution in accordance with the compaction requirements of the public road bedding.

Soil compaction tests shall be carried out according to the relevant standards.

D.4.4.13 Allowance for settlement

The Contractor shall make due allowance for consolidation and settlement of fill and compacted fill such that the levels and dimensions of the finished surfaces at the end of the Contract (Defects Notification Period) are within the tolerances specified.

D.4.4.14 Disposal of surplus Material

The disposal of surplus backfill material shall be deemed to be included in the rates for the respective backfilling operations.

The Contractor shall make his own arrangements to dispose of all surplus backfill and unsuitable excavated material from any part of the Work. The material shall become the property of the Contractor and the Contractor shall dispose such material off-Site at locations to be determined by the Contractor and to be approved by the relevant authorities.

The Contractor shall clean the Site and the surrounding ground immediately after completion of works and leave the construction sites clean and tidy to the satisfaction of the Engineer.

D.4.5 Backfilling Sundries

D.4.5.1 Backfilling under paved Areas

When excavation is made in highways, other public roads, sidewalks or any other paved area, the trench shall be backfilled and thoroughly compacted only with a stone embankment (buffer layer).

The remaining top of the trench shall be filled with graded and well compacted aggregate up to the top of the base of the pavement.

The further reinstatement of surfaces shall correspond to the existing pavements.

D.4.5.2 Backfilling around Chambers

Backfilling around chambers and material used for it shall meet the specifications set out for the backfilling of adjacent trenches.

In roads with a width over 3 m, the material around chambers shall be selected and compacted to meet the requirements of bearing and buffer layer.

D.4.5.3 Backfilling in agricultural Land

If pipe alignments cross agricultural land and green areas (public and private), the trench shall be backfilled to the top of adjacent land; whereby the top 30 cm of the trench shall be filled with the agricultural or green area top soil originally found before excavation.

D.4.5.4 Backfilling in Water Courses

In riverbeds the pipes shall be fully encased with reinforced concrete and the top of the excavation shall be covered with gabions, laid by hand and extending 1 m on either side of the excavated trench; likewise in ditches clad with masonry, the masonry shall be reinstated after completion of backfill with concrete and in small ditches without any surface cladding the trench shall be backfilled to the invert of the ditch with concrete. Concrete shall be reinforced with 80 kg/m³ steel. Concrete shall be of class C 20/25.

D.4.5.5 Field Drains

Should any existing subsoil or field drains be uncovered during general excavation, the Contractor shall either carefully replace them when backfilling, or, if this is impracticable, shall divert them to new drains or ditches, or otherwise relay them as the Engineer may direct.

D.4.6 Embankments

D.4.6.1 Embankments in General

The term “embankment” includes the construction of embankments around structures, hard or other backfill, embankments for road works and the like.

Backfilling to general excavations, the forming of soil tips and the re-filling of trenches are specified and included in the clauses dealing with backfill.

D.4.6.2 Materials for Embankments

Excavated material (including material from borrow pits) to be used as fill material for embankments shall be free from clods and lumps and shall be approved by the Engineer.

If not otherwise directed, cohesive soil shall be placed in layers not exceeding 200 mm in compacted thickness; cohesionless soil shall be placed in layers not exceeding 300 mm in compacted thickness.

Material for hard filling shall be as specified below.

Should the material being placed as filling, while acceptable at the time of selection, become unacceptable to the Engineer due to exposure to weather conditions or due to flooding or become puddled soft or segregated during the progress of the works, the Contractor shall remove such damaged, softened or segregated material and replace it with fresh approved material.

D.4.6.3 Filling with Hardcore

All fill under structures, unless indicated otherwise on approved drawings or instructed by the Engineer, shall be constructed with hardcore obtained from sources approved by the Engineer.

Hardcore shall be hard inert material passing a 75 mm sieve and be free from clay, silt, soil and vegetable matter and shall not deteriorate in the presence of water.

Hardcore shall be placed in layers not exceeding 150 mm thickness after consolidation and each layer shall be compacted by mechanical means. The final surface of hardcore shall be blinded with fine crushed stone and thoroughly compacted.

D.4.7 Reinstatement and Maintenance

D.4.7.1 Reinstatement of paved Surfaces

The Contractor shall restore all pavements or other surface structures removed or disturbed as a part of the work to a condition suitable and satisfactory to the Engineer.

No pavement shall be restored unless and until, in the opinion of the Engineer, the condition for backfill is given in such a way as to properly support the pavement.

The reinstatement of road surfaces and other pavements will be commenced upon approval of the Engineer of the completed backfill and shall be done, if not otherwise stated, as follows:

- The top of the pipe trench (below the top of the base) shall be filled with graded aggregate (0 - 60 mm of natural stabilized material), watered, placed in layers of max. 15 cm thickness and compacted to not less than 95 % of maximum dry density according to modified proctor test.
- At pipeline crossings, the top 30 cm of the trench shall be filled with plain concrete C 12/15.
- At the top of the bearing layer, the width of the trench shall be increased for 15 cm on each side. In order to ensure appropriate adjustment of the surfaces the Contractor shall use such methods as will ensure the cutting of the pavement in straight lines. The profile of the remaining pavement after cutting should be approximately vertical.
- The surface shall be restored in accordance with the existing pavement and/or instructions of the Engineer.

D.4.7.2 Reinstatement of unpaved Surfaces

Gravel roads and unpaved roads shall be reinstated to their original condition. If the original road construction cannot clearly be applied, then 100 mm approved large gravel and 150 mm well-graded gravel compacted to 95 % of maximum density shall be provided.

D.4.7.3 Surface Reinstatement in agricultural Fields

After the Contractor has completely backfilled the trenches in fields and grass verges to the level specified, he shall replace all topsoil previously removed and it shall be evenly distributed and levelled over the full extent of the stripped area.

Such working area occupied by the Contractor as was originally grown with grass shall be sown with grass seed of equivalent quality and maintained until the new grass is properly established.

Other areas not originally down to grass shall be dressed with suitable fertilisers harrowed in so as to restore the original level of fertility.

D.4.7.4 Reinstatement of existing Services

Where excavation is carried out close to or across the line of sewers, pipes, cables or other services, whether underground or overhead, the Contractor shall, where necessary, provide at his own cost temporary supports or slings and where such services are temporarily disturbed, they shall be replaced.

D.4.7.5 Reinstatement of Hedges, Fences and Walls

Where excavation disturbs features such as hedges, fences and walls, the Contractor shall, as a temporary measure, provide temporary fencing for any such parts of such barriers.

After excavation has been reinstated, the Contractor shall carry out such work as approved by the Engineer for permanent restoration of such barriers.

In the case of hedges, if possible, the same shall be dug up by the root and temporarily moved to a suitable location with regular maintenance and returned to the same place after the completion of works, if this is not possible, the removed part shall be replaced with seedlings of appropriate plant species along with the installation of posts and barbed wire fences on both sides.

During the Defects Notification Period all hedges replanted in the above manner shall be inspected and any dead sapling replaced by the Contractor.

The reinstatement of the backfilled surface shall include (1) the re-excavation of the top surface, base and sub base, (2) compacting the backfill in the trench, (3) backfilling the base and sub base with graded aggregate and (4) reinstatement of the surface according to surface conditions met before.

D.4.8 Auxiliary Works

Unless otherwise specified, all and any kind of works, materials, services, safety measures, etc., as well as, and if so requested by the Engineer, all tests and samples required for the Completion of the Works shall be included in the unit rates offered. Hence, the auxiliary works comprise, but are not necessarily limited to, the following:

- Removing and storing of boundary stones, bench marks, etc., protection of surveying points and designation by means of boards, survey and protection of all secondary survey points, profiles, etc.;
- Difficulties to be overcome in places where manual excavation may be necessary (except in places where it is stipulated by the bill of quantities) or excavation in layers;
- Keeping off or diversion of water, any pumping required, difficult work caused by water, etc.;
- Removal of all obstacles, buried pipes, foundation remains, the like that might interfere with excavation profiles;
- Difficulties resulting from the specifications relating to fills, compaction tests, eliminating unsuitable material from fills, and, if necessary, mixing of different soil materials;
- Use of public roads with alternative routes to the construction site;
- Transport of excavated material to fill or deposit, placing and spreading in layers according to conditions and drawings, and careful compaction;
- Difficulties in transport due to existing subsoil conditions;
- Grading of intermediate and top fill surfaces and slopes to lines and levels required;
- Sorting of excavated material which, if necessary, is to be used for special purposes;
- Any expenditure for providing, maintaining and later removal of drive ways and roads, providing, placing, maintaining and later removal of conveying and dumping equipment that might be required.

D.4.9 Dewatering

Dewatering applies for all filling works to be carried out below the groundwater level. Dewatering shall be done by pumping out the water from drains, pits and trenches or by other dewatering means, all subject to the Engineer's approval.

The Contractor shall maintain all earthworks surfaces in a way that no water coming from any source can penetrate into it to soften and destroy the achieved compaction. Hence all works shall be implemented above the water level and be considered as earthworks in a dry and maintained environment. In such cases, the pump should run for 24/7.

Furthermore, dewatering should avoid any erosion of filled material. This applies especially for surfaces and slopes. In case surfaces have to be reinstated because of erosion, the Contractor shall bear all costs connected to it. The Contractor shall keep the site reasonably free from water, as long as work is being performed within them. In case, the presence of water is considered endangering the works, dewatering operation shall continue until elimination of the danger.

It is recommended that the final layers of built platform should be compacted to show a roof shape of which the lowest parts are supplied with temporary drains.

D.4.10 Top Soil

So far as practicable, topsoil shall be obtained from material emanating from excavations and separately stored in temporary spoil tips as specified or directed by the Engineer.

If, in the opinion of the Engineer, the Contractor cannot reasonably obtain sufficient topsoil of a good quality in this way, the Engineer may order the Contractor to provide extra material from an approved source off the Site.

Topsoil shall be evenly spread and trimmed over embankments and filled excavation to the slopes and levels as shown on the Contractor's approved shop drawings. The depth after spreading and trimming shall be 250 mm measured perpendicular to the surface. All clods and lumps shall be broken up and any rubbish, large stones, roots and weeds shall be removed.

Where the upper layer of natural soil is poor in organic matter, it shall be improved to a minimum depth of 25 cm by adding either clay or sand or silt to create a loamy soil texture consisting of 40 % sand (size > 0.05 mm), 30 % silt (size 0.05 to 0.002 mm) and 30 % clay (size < 0.002 mm).

A shallow ripping will be required before adding clay or sand or silt which shall be mixed properly by using a disk harrow. If it shall be necessary for topographical reasons, levelling shall be carried out before mixing clay, sand or silt.

D.4.11 Grassing

Where the topsoil shall be sown with grass seed, the top 75 mm of the previously laid topsoil shall be brought to a fine tilth suitable for seeding, and sowing shall be carried out as soon as practicable after completion of top soiling, having due regard to the season and the weather conditions. If ordered by the Engineer, subsoil lime and fertiliser shall be applied in accordance with his directions.

After the seed has been sown uniformly, the surface shall be raked and lightly rolled. The young grass shall be kept free from weeds and any bare patches shall be re-seeded until an even close turf is established. The grass shall be watered, mown and rolled as required and maintained in good condition until the expiry of the Defects Notification Period.

The Contractor shall replace, at his own cost, any damaged area where the grass has dried up or has not adhered to the slope surface, which contains undesirable plants or which has an irregular or unattractive appearance in the Engineer's opinion.

D.4.12 Shrubs and Trees

Shrubs for borders and hedges shall have a minimum height of 0.6 m. A selection of 2 plants per m² are to be planted to create an evenly dense area.

Trees to be supplied and planted shall have a minimum height of 1.5 m.

For the plant holes, vegetable soil is to be used. Stabilization of freshly planted trees against wind actions shall be provided. Shrubs and trees shall be suitable for the climatic conditions on Site. The Engineer shall approve the species the Contractor intends to plant.

Growth of shrubs and trees shall be guaranteed for one year from the day of planting. Any shrubs and trees which have died within the guarantee period must be substituted without extra payment.

D.4.13 Dressing of Topsoil

After planting of lawn, shrubs or trees, the topsoil shall receive a dressing of fertiliser. As minimum requirements, dressing of topsoil shall be done with lime, potash and super-phosphate, as applicable.

Dressing of topsoil shall only be carried out after watering. The surface of the soil shall be kept wet until fertilisers have dissolved.

D.5. Piling

D.5.1 General

The piling works required to include all materials, labour, equipment, testing and all operations under this item to complete the work indicated on drawings and described in these specifications.

The Contractor has to submit the system he will be using for construction to be approved by the Engineer.

The Contractor is not obliged to use the proposed design for piles. In case he has another alternative, he must submit this alternative to the Engineer to be checked and approved. The loads acting on piles are given in the Contractor's approved shop drawings.

The Contractor is responsible for the setting out of piles. He has to obtain written agreement of the Engineer to the setting out. This agreement does not remove the responsibility of the Contractor for the correctness of work.

D.5.2 Materials and Workmanship

The lengths of piles may be varied by instructions of the Engineer as a result of data derived from the driving and/or test loading of driven, cast-in situ or bored piles, or as a result of further detailed information obtained as to the soil characteristics.

Piles shall be installed using approved piling plant appropriate to the ground conditions and the design loads.

Installation of piles must not affect in any way the stability of the neighbouring structures.

Bored piles shall be formed by methods approved by the Engineer and shall comply with EN 1536 and/or other equivalent applicable standards.

The quality of production of bored piles and cast in situ concrete shall be

Drilling if bored using stabilizing suspension: $\geq 1\text{m}$ excess pressure by suspension

if bored using a piping: $\geq 1\text{m}$ excess pressure by water

Using a stabilizing suspension: the contractor has to prove that the stabilisation of the suspension will not collapse

Groundwater groundwater has to be investigated with respect to concrete aggressiveness acc. to ISO 22475-1/2. Appropriate corrective measures shall be taken in the mix design to counteract any deleterious properties of the ground water.

Mix design The concrete has to be a watertight concrete. The mix design has to be submitted to the site supervision for approval, at least 4 weeks before starting the production of piles

Exposition Class XA2, if investigation of groundwater does not demand higher exposition class

Limitation of cracks $\leq 0,3\text{ mm}$ in case of exposition class XA3 $\leq 0,2\text{ mm}$

Concrete Class according to statical requirements, but $\geq \text{C } 25/30$,

Cement sulphate resisting cement, HS

Cement content $\geq 375\text{ kg/m}^3$

Water-cement ratio $< 0,6$

Aggregates pile diameter 0,4 m: 0/16

pile diameter > 0,4 m: max grain size 22 mm is proposed favourable range of grain sizes:

Longitudinal reinforcement $d \geq 16$ mm

Spacing of longitudinal bars ≥ 10 cm

Secondary (spiral) reinforcement $d \geq 6$ mm

Coverage depended on exposition class ≥ 50 mm if borehole is cased, in case of drilling using stabilizing suspension the theoretical coverage is ≥ 75 mm

After production the quality of the production of all piles has to be tested by accepted testing method (integrity checking: Low-Strain, High-Strain, Down-Hole or equivalent).

The piles shall be reinforced in their full length. Reinforcement of piles shall extend sufficiently to be incorporated with the capping reinforcement with at least the minimum laps specified. The details of all capping arrangements shall be subject to the Engineer's approval.

Piles shall be driven or cast truly vertical or to the required rake and piles inaccurately driven or positioned, or piles damaged shall be rectified as required by the Engineer.

A record of the pile installations work and associated observations shall be submitted to the Engineer at the end of each day of work.

The records shall contain description of penetrated deposits and measurement of the associated interface levels of each type of deposit.

In additions the records shall include information on date, operator, piling equipment, duration of work in the different strata, type of pile, water level before and after the installation, toe level, water jetting, if any, and the name of the foreman or supervisor in charge.

Before installation all piles shall be marked per m in the whole length with clear indication of the figures from toe to top.

All piles shall be subject to approval by the Engineer before and after installation. Piles may be rejected by the Engineer if they appear to have been damaged, cracked, located out of the line or tolerance, incorrectly fabricated, marked, stored or handled, or they have been lengthened in a way that is not approved. Rejected piles shall be substituted by other piles as directed by the Engineer, and rejected piles, not left embedded in the soil, shall promptly be removed from the site as directed by the Engineer.

Where, in the opinion of the Engineer, incorrectly placed, inaccurately installed or damaged piles can result in the necessity for installing additional piles or altering the capping arrangement, all such additional material, labour, plant, etc, as may be required, shall be provided to the Engineer's satisfaction.

Piles selected by the Engineer shall be test loaded to 1,5 times their working load. The number of all piles justifies a number of at least 3 pile load tests. The charges have to be included in the unit rates.

The Contractor shall provide all necessary apparatus and assistance for the testing of piles as required by the Engineer.

D.5.3 Concrete Pile Foundations

D.5.3.1 Standards

In addition to the standards as listed, the following standards shall apply:

- ASTM D 1143 Piles under static axial compressive load

- ASTM D 3689 Test method for individual piles under static axial tensile load
- ASTM D 3966 Test method for piles under lateral loads
- ASTM D 4945 Test method of high strain dynamic testing on piles
- ASTM D 5882 Test method of low strain dynamic testing on piles
- EN 1536 Bored piles
- ENV 1997 Eurocode 7: geotechnical design
- EN 12699 Displacement piles

D.5.3.2 General

Pile foundation may be necessary for supporting structures where the subsoil is considered to have insufficient bearing capacity. The Contractor shall carry out detailed design of these structures in accordance with the Contract Conditions and technical specifications and shall determine the type of foundation required, the number of piles and their working loads and the optimum arrangement of piles required for supporting the structures.

Excavation, concrete steel reinforcement and steel casing where applicable shall conform to the relevant Clauses of the technical specifications.

At least 21 days before the Contractor intends to commence piling work on the site the Contractor shall submit for the Engineer's approval full details of his proposed piling system including the type and dimensions of piles, reinforcement details and full details and full design and driving calculations. The details to be submitted shall include the Contractor's proposals for equipment, temporary works and construction methods.

No work on piling shall commence on the site until the Engineer's approval to the Contractor's proposal has been received.

D.5.3.3 Types of Piles

Bearing piles shall be driven reinforced concrete, precast concrete or cast in-situ concrete piles. All concrete shall be in sulphate resisting cement.

D.5.3.4 Design of Piles

Piles shall be generally designed in accordance with appropriate standards and the materials and work shall conform to the requirements of the technical specifications. Piles shall be designed to sustain the specified loads with settlements not exceeding those specified. Allowance shall be made in the design for the incidence of negative skin friction where appropriate and for resisting the necessary tensile forces due to the swelling and heave of any soil stratum. Piles shall be designed to have a bearing capacity of at least 2,5 times the working load.

The permissible load of piles shall be modified where necessary to allow for particular conditions: piles in close proximity or in groups, soil strength, groundwater level, and other relevant factors.

The piles shall be of sufficient cross-section and length to sustain loads specified without settlement exceeding the following:

- 1,0 x working load Allowable settlement 8 mm
- 1,5 x working load Allowable settlement 10 mm
- 2 x working load Allowable settlement 12 mm

These settlements shall include both permanent and elastic deflections. Measurement of the settlement shall be made on first achieving the specified load. Measurement of the settlement shall be made at the point of application of the load.

Where piles in place are subjected to handling, stacking and pitching or bending moments and/or shear forces, these shall be combined with the vertical loads (either in compression or tension) to satisfy the design requirements.

The average compressive stress in the concrete of bearing piles under working load shall not exceed 25 % of the characteristic cube strength at 28 days, calculated on the total cross-section area of the pile shaft.

D.5.3.5 Preliminary Test Piles

After the Engineer has approved the Contractor's proposals and calculations for the proposed piling system, preliminary test piles shall be constructed as instructed by the Engineer. These shall be loaded to 2,0 times the working load to prove the design and system and to demonstrate that the safe load requirements can be achieved by the piling method proposed.

The preliminary test piles shall be located in places proposed by the Contractor and approved by the Engineer. The Engineer shall be given at least 48 hours notice before commencement of construction of the preliminary pile which is to be test-loaded.

The preliminary test piles shall be constructed / installed in a manner similar to that to be used for the construction of the working piles by the use of similar equipment and materials. Any variation will only be permitted with the prior approval of the Engineer.

The pile shafts shall be extended where necessary above the cut-off level or working piles so that gauges and other apparatus to be used in the testing process will not be damaged by water or failing debris and to permit exposure of the reinforcement.

Where the pile shaft is extended above the cut-off level of the working piles in soils which would influence the load bearing capacity of the pile a sleeve shall be left in place during testing to eliminate friction which would not arise in working piles.

If the cut-off level is below ground level and the shaft is not extended and there is a risk of the borehole collapsing, a sleeve shall be left in place or inserted above the pile shaft or other means satisfactory to the Engineer shall be employed. Adequate clearance shall be given between the top of the pile shaft and the bottom of the sleeve to permit unrestricted movement of the pile.

For piles that are tested in compression the pile head or cap shall be formed to give a plane surface which is normal to the axis of the pile sufficiently large to accommodate the loading and settlement measuring equipment and shall be adequately reinforced or protected to prevent damage due to the concentrated application of load from the loading equipment.

The pile cap shall be concentric with the test pile and the joint between the cap and the pile shall have a structural strength equivalent to that of the pile.

A sufficient clear space shall be made under any part of the cap projecting beyond the part of the pile so that at the maximum anticipated settlement, load is not transmitted to the ground except through the pile.

The connection between the pile and the loading equipment shall be constructed in such a manner as to provide a strength equal to the maximum load which is to be applied to the pile during the test with an appropriate factor of safety on the structural design.

If the preliminary test pile fails to meet the requirements of the technical specifications, the piling system proposed will be considered unsatisfactory. The Contractor shall then submit revised proposals and calculations to the approval of the Engineer. Unless otherwise agreed by the Engineer any test pile which has failed the preliminary test will be rejected

and the Engineer may instruct the Contractor to provide one or more further test piles and tests to prove his modified system at no additional cost to the Employer.

D.5.3.6 Lengths and Tolerances

The Contractor shall determine the approximate lengths of piles by examination of the available geo-technical information including information obtained from any additional site investigations carried out by the Contractor. The final length of piles shall be decided by constructing the piles to a minimum depth on the basis of the geo-technical information.

Precast piles shall be constructed within the following tolerances:

- in plan, at the working level of the piling rig $0,15 \times B$ in any direction from the designed position. B = pile dimension (diameter or side)
- $1/75$ from the vertical for a vertical pile

The cross-sectional dimensions of the pile shall not be less than those proposed by the Contractor nor should they exceed them by more than $0,015 \times B$ (B = pile dimension, diameter or side). No face of a precast pile shall deviate by more than 6 mm from a straight edge 3 m long laid on the face. The centroid of any cross-section of the pile shall not deviate by more than 12 mm from the straight line connecting the centroids of the ends.

D.5.3.7 Sequence for Constructions

The sequence of construction of piles shall be to the approval of the Engineer and shall be arranged so as to minimise the vertical and lateral displacement of piles already installed. Levels of the tops of adjacent piles or the structures founded upon them or any other structure shall be measured at intervals while a pile is being installed. Driven piles driven which have risen, shall be re-driven or forced down to the original resistance.

D.5.3.8 Driving Piles

The Contractor shall submit for the Engineer's approval details regarding the suitability efficiency and energy of his driving equipment.

Precast (prestressed) concrete piles shall not be driven until the concrete has achieved the specified characteristic strength.

Cast-in-situ driven piles with steel casing shall be bottom driven by using a casing which shall not distort or buckle during driving. Concrete casing shall be driven on the pile shoe using a mandrel.

Each pile shall be driven continuously until the approved set and/or depth has been reached except that the Engineer may permit the suspension of driving will be substantially re-established on its resumption or if he is satisfied that the suspension of driving was beyond the control of the Contractor.

A follower (long dolly) shall not be used except with the approval of the Engineer who will then require the set to be revised to take into account the reduction in the effectiveness of the hammer blow.

The final set of each pile shall be recorded either as the penetration in mm per 10 blows or as the number of blows required to produce a penetration of 25 mm. When a final set is being measured, the following requirements shall be met:

- a) The exposed part of the pile shall be in good condition without damage or distortion;
- b) The dolly and packing if any shall be in sound condition;

- c) The hammer blow shall be in line with the pile axis and the impact surfaces shall be flat and at right angles to the pile and hammer axis.

The Contractor shall give adequate notice and provide all facilities to enable the Engineer to check driving resistances. A set for the purposes of the Contractor shall only be taken in the presence of the Engineer unless otherwise agreed.

At the start of the work and in new areas or parts, sets shall be taken at intervals during the last 3 m of driving to establish the behaviour of piles.

The Contractor shall inform the Engineer without delay if an unexpected change in driving characteristics is noted. A detailed record of driving resistance over the full length of the nearest available pile shall be taken.

Redrive checks if required shall be carried out by a procedure to be agreed by the Engineer.

Piles shall be driven in an approved sequence to minimise the detrimental effects of heave and lateral displacement of the ground.

Measurements shall be taken to determine the movement of ground or any pile resulting from the driving process when required by the Engineer.

Where piles have risen or moved out of plumb as a result of driving adjacent piles the Contractor shall submit to the Engineer his proposals for correcting such faults and their avoidance in subsequent work.

Where pre-boring is required by the Contractor each pile shall be pitched into a hole pre-bored before driving to the required depth.

Jetting may be carried out only when approved by the Engineer and the Contractor shall submit detailed proposals and it shall not normally be undertaken over the last 3 m of penetration.

D.5.3.9 Repair and Lengthening of Piles

In preparation for repairing the head of a pile, the concrete shall be cut off square at sound concrete to expose the reinforcement and all loose particles shall be removed by wire brushing followed by washing with water.

If the pile is to be subjected to further driving the head shall be replaced with concrete of an approved class.

If the pile has been completely driven but the sound concrete is below cut-off level the pile shall be made good to cut-off level with concrete of a class not inferior to that of the concrete of the pile.

In preparation for lengthening a normal reinforced pile, the concrete shall be cut off square to expose a sufficient length to ensure that the full strength of the bars will be developed across the joint.

Welded joints shall be made in accordance with ISO 17660, ISO 10809, ISO 5817 or equivalents and before welding the main longitudinal reinforcing bars in the head of the pile shall be exposed for at least 300 mm below the position of the weld.

For lap or splice joints sufficient link bars shall be provided to resist eccentric forces.

If the pile is to be subjected to further driving the additional length shall be of an approved grade of concrete. Piles shall not be driven until the added concrete has reached the specified characteristic strength of the concrete of the pile.

D.5.3.10 Reinforcement

Unless otherwise stipulated by the design, cast in situ piles shall be reinforced over the whole of their length. The minimum longitudinal reinforcement shall be 1,0 % of the gross concrete area in the top 3 m of the pile and 0,8 % of the

gross concrete area in the remainder of the pile. Lateral ties shall be provided to maintain the alignment of the longitudinal reinforcement at centres not closer than 150 mm.

Concrete cover in-situ piles to the outermost reinforcement, including binding wire shall not be less than 60 mm measured to the inside of the casing.

D.5.3.11 Pile Shoes

Driven piles shall be provided with flat or pointed co-axial shoes of cast iron if driving is liable to damage the concrete at the tip of the pile.

Cast iron pile shoes shall be made from "chill hardened" iron of the grade used for making grey iron castings. The chilled iron point shall be free from major blow holes and other surface defects.

D.5.3.12 Records

The Contractor shall maintain a complete record of all piling works which shall include the following, where relevant:

- Pile type and number;
- Nominal diameter or dimension and pile length;
- Date concreted and date driven;
- Depth from ground level to toe of pile;
- Depth from ground level bearing stratum;
- Final set, weight and drops of hammer;
- Details of any obstructions observed.

All records shall be accurately kept in duplicate as the work proceeds and one copy shall be handed to the Engineer at the completion of each day's work.

D.5.3.13 Precast Reinforced Concrete Piles

D.5.3.13.1 General

Precast reinforced concrete piles shall be designed cast and cured to develop the strength necessary to withstand the transporting, handling and driving stresses without damage. Square piles shall have chamfered corners. Manufacturing and curing shall be in accordance with International standards.

D.5.3.13.2 Handling of Precast Piles

Precast (prestressed) concrete piles shall be handled, transported, and stored by methods that will not injure the pile. The piles shall be supported while being handled, transported, and stored, at the pick-up points shown on the plans, or else shall be supported along their full length. Piles damaged in handling or driving shall be replaced by the Contractor.

D.5.3.14 Cast-In-Situ Piles

D.5.3.14.1 Driven or Bored Cast-In-Situ Piles

Driven or bored cast-in-situ piles shall comprise a temporary or permanent casing of steel, or a permanent casing of precast concrete, augered or driven to a set and completely filled with dense concrete reinforced with steel bars.

All joints in the casing and between the casing and shoes where applicable shall be watertight during driving and completion of driven cast-in-situ piles. Permanent casing shall be inspected, e.g. by using a light lowered from the top after installation to ensure that the casing is neither damaged nor deformed and that all loose soil has been removed from the bottom of bored piles.

Drilling mud shall not be used unless otherwise approved by the Engineer.

D.5.3.14.2 Casing for Cast-In-Situ Piles

The casing shall be suitable for the method of installation and for the purpose of jointing piles. The casing shall either be permanent or temporary.

Steel casing shall be delivered to site in lengths as long as can be conveniently handled. Ends shall be prepared for butt welding and designed to maintain true alignment of the pile.

Joints between steel casings shall be made by butt welding according to ISO 17660, ISO 10809, ISO 5817 or equivalents so that the full strength of the original part is developed. Welded joints shall be watertight.

D.5.3.14.3 Concrete Cast-In-Situ Piles

The slump for the concrete shall be agreed with the Engineer prior to concreting preliminary test piles. Concrete filling in cast-in-situ piles shall be placed continuously. Removal of temporary casings must be completed before the placed concrete loses its workability, but placing of concrete shall keep in advance of withdrawal of casing to prevent 'necking'.

Pile heads shall be stripped down and bonded into the pile caps as specified for precast concrete piles.

D.5.3.15 Pile Load Tests

Pile load tests shall be carried out in the following situations:

- When using a type of pile or installation method that is outside comparable experience and which has not been tested under comparable soil and loading conditions;
- When using a piling system which is outside the experience of the operatives carrying out the work;
- When the piles will be subject to loading for which theory and experience do not provide sufficient confidence in the design. The pile testing procedure should then provide loading similar to the anticipated loading;
- When observations during the process of installation indicate pile behaviour that deviates strongly and unfavourably from the behaviour anticipated on the basis of the site investigation or experience and when additional ground investigations do not clarify the reasons for this deviation.

Load test can be static or dynamical.

If a load test is carried out, it shall normally be located where the most adverse ground conditions are believed to occur. If this is not possible, an allowance shall be made when deriving the characteristic value of the bearing resistance.

If load tests are carried out on two or more test piles, the test location shall be representative of the site of the pile foundations, and one of the test piles shall be located where the most adverse ground conditions are believed to occur.

Between the installation of the test pile and the beginning of the load test, adequate time shall be allowed to ensure that the required strength of the pile material is achieved and the pore pressures have regained their initial values.

D.5.3.15.1 Static Load Tests

Loading Procedure

The pile load test procedure, particularly with respect to the number of loading steps, the duration of the loading steps and the application of load cycles, shall be such that conclusions can be drawn about the deformation behaviour, creep and rebound of a pile foundation from the measurements on the pile. For trial piles, the ultimate loading shall be such that conclusions can also be drawn about the ultimate failure load.

Static load tests shall be carried out in accordance with the respective standard. In case of different wording, the text in this technical specifications shall be valid prior to the above mentioned recommended procedure.

Devices for the determination of forces, stresses or strains and displacements shall be calibrated prior to the test.

In general, pile load tests for the purpose of designing a tensile pile foundation should be carried out to failure. Extrapolation of the load-displacement graph for tension tests should normally not be used, especially in the case of transient loading.

Trial Piles

The number of trial piles required to verify the design shall be selected based on the following aspects:

- the ground conditions and their variability across the site;
- type of structure;
- documented evidence of the performance of the same type of pile in similar ground conditions;
- the total number and types of piles in the foundation design. The ground conditions at the test site shall be investigated thoroughly. The depth of borings or field tests shall be sufficient to ascertain the nature of the ground both around and beneath the pile tip. It shall include all strata likely to contribute significantly to pile deformation behaviour, at least 5 times the diameter beneath the pile tip, unless sound rock or very hard soil is found at a lesser depth.

Working Piles

The number of working pile load tests shall be selected on the basis of the recorded findings during construction.

The selection of the working test piles should be prescribed in the contract documents.

The load applied to the working test piles shall be at least equal to the design load governing the design of two foundations.

D.5.3.15.2 Dynamic Load Tests

Dynamic load tests shall be carried out in accordance with the respective standards.

The results of dynamic load tests may be used for design, provided an adequate site investigation has been carried out and the method has been calibrated against static load tests on the same type of pile, of similar length and cross-section, and under comparable soil conditions.

Dynamic load tests may be used as an indicator of the consistency of the piles and to detect weak piles.

In a dynamic load test the pile is instrumented with accelerometers and strain gauges. The gauges are connected to a recording and data processing device. During blows on the pile signals from the gauges are recorded and processed for assessment of pile bearing capacity. The data processing will be one of two kinds, either simple or signal matching (CASE or similar program). The simple method gives instant results while signal matching is more time consuming (hours).

In the CASE method or similar the following data shall be registered and reported:

- bearing capacity;
- toe resistance and skin friction;
- maximum compression stress, acceleration, velocity and displacement;
- maximum tension stress in pile;

- pile structural integrity; extent and location of damage;
- maximum energy transferred to the pile;
- blows per minute for hammer check;
- blow number;
- input and reflection of force, velocity, upward and downward force waves;
- load versus deflection of cushions and of pile toe bearing.

CAPWAP or similar programs determines that set for soil resistance parameters which produces the best match between measured and computed pile top force and velocity. After CAPWAP analysis additional information than above for CASE is accomplished as:

- deformation properties, ultimate capacities and soil damping parameters for each soil segment of normally 1 m length;
- unit skin friction for each segment and end bearing;
- maximum of tension and compression forces and stresses;
- pile structural damping;
- dynamic pile toe displacement;
- graph on bearing capacity and pile stresses versus blow count.

An introductory program (WEAP) can be utilised before pile driving to assess preliminary combinations of sets and bearing capacities for specified pile, driving equipment and soil conditions.

The data processing shall be carried out by well experienced experts.

Dynamic Load Test Procedure

The Contractor shall notify the Engineer at least two weeks prior to dynamic testing.

The Contractor shall submit a qualified testing Consultant and his experience to the Engineer for approval.

The Engineer shall determine if the test is to be performed or if some pile waiting periods at the proposed site is required before a decision will be made.

The Engineer will establish a date for the tests and will also determine the location of all piles to be dynamically load tested.

Dynamic Load Test Procedure on Driven Piles

The Contractor shall supply all personnel and equipment needed to strike the test pile with the hammer.

The Contractor shall provide the hammer (drop, diesel, etc.) or the mobile crane to lift a steel ram weight by a single non- twisting cable and be able to strike to the pile top by mean of full-gravity-fail.

The instrument for the dynamic load test shall conform to the standards, e.g. ASTM D 4945.

Approximately two driven piles will be tested in one day. The testing Consultant personnel will drill holes into the pile to be tested so that transducers (two accelerometers and two strain gauges) can be attached. Testing procedures shall be conformed to e.g. ASTM D 4945.

When the transducers have been placed in position and the recording and processing equipment has been made ready to receive the acceleration and strain measurements, the Engineer will instruct the Contractor regarding the drop height and

the Contractor shall strike the driven pile with the hammer as many times as is required to obtain adequate measurements as determined by the Engineer.

The Engineer may ask the Contractor to provide surveying instrument to monitor the pile set after each strike.

After the dynamic testing measurements have been obtained and analysed and a report has been submitted, the Engineer will provide instructions for the results.

Dynamic Load Test Procedure on Bored Piles

The Contractor shall prepare the pile top and if necessary improve the structural integrity of the pile top to resist a sharp impact force. All loose concrete at the pile top shall be removed. The top portion of the bored pile shall be extended to a length of at least two times the diameter of the bored pile with the same diameter as the bored pile. The extended portion of the bored pile shall be cast with concrete having a minimum compressive strength of 40 MPa.

Additional shear reinforcement such as spiral hoop at the pile top is recommended for the impact force. The Contractor shall provide the windows for the installation of instrument by burning an opening 0,35 x 0,35 m² to the steel casing using a cutting torch.

On top of the bored pile a timber cushion under steel plate as a hammer cushion shall be mounted. Adhesive material may be applied between the pile top and the timber.

The Contractor shall provide an additional steel casing inserted into the pile top. This casing is acting as a guide for the steel ram weight, having the length not less than the summation of the drop height and the length of the steel ram weight. It is important to secure and stabilise the steel casing by means of a vibratory hammer.

The Contractor shall supply all personnel and equipment needed to strike the test pile with the steel ram weight. The Contractor shall provide a mobile crane which has the ability to lift the steel ram weight by a single non-twisting cable and be able to strike to the pile top by mean of full-gravity-fall.

The instrument for the dynamic load test shall conform to e.g. ASTM D 4945.

Approximately one bored pile will be tested in one day. The testing Consultant personnel will drill holes in the windows of the left-in-place steel casing into the pile to be tested so that transducers (two accelerometers and two strain gauges) can be attached.

Testing procedures shall be conformed to e.g. ASTM D 4945.

The Engineer may ask the Contractor to provide surveying instrument to monitor the pile set after each strike.

After the dynamic testing measurements have been obtained and analysed and the report has been submitted, the Engineer will provide instructions for the results.

Load Test Report

The Contractor shall submit a complete record of each pile test to the Engineer 24 hours after completion of the tests. Where appropriate, this report shall include:

- a description of the site;
- the ground conditions with reference to ground investigations;
- the pile type;
- a description of the loading and measuring apparatus and the reaction system;
- calibration documents of the load cells, the jacks and the gauges;

- the installation record of the test piles;
- photographic records of the pile and the test site;
- test results in numerical form;
- time settlement plots for each applied load when a step loading procedure is used;
- the measured load-settlement behaviour;
- justification of the reasons for any departures from the recommendations;

D.5.3.16 Piles in Compression

D.5.3.16.1 Ultimate Bearing Resistance from Static Pile Load Tests

Trial piles to be tested shall be installed in the same manner as the piles which will form the foundation and shall be founded in the same stratum.

In the case of a very large diameter pile, it is often impractical to carry out a load test on a full size trial pile. Load tests on smaller diameter trial piles may be considered provided that:

- the ratio of the trial pile / working pile diameter is not less than 0,5;
- the trial pile is instrumented in such a manner that the base and shaft resistance can be derived separately from the measurements. When deriving the ultimate characteristic bearing resistance R_{cc} from R_{cms} values measured in one or several static pile load tests, an allowance shall be made for the variability of the ground and the variability of the effect of pile installations, at minimum, both conditions (a) and (b) of the table below shall be satisfied using the equation:

$$R_{cc} = R_{cms} / \gamma_{ns}$$

Factors γ_{ns} to deduce R_{cc} :

Number of Load Tests	1	2	> 2
γ_{ns} on average R_{cms}	1,5	1,35	1,3
γ_{ns} on lowest R_{cms}	1,5	1,25	1,1

In order to derive the ultimate design bearing resistance, the characteristic value R_{cc} should be divided into components of base resistance R_{bc} and shaft resistance R_{sc} such that:

$$R_{cc} = R_{bc} + R_{sc}$$

The design bearing resistance R_d shall be derived from:

$$R_d = R_{bc} / \gamma_{bs} + R_{sc} / \gamma_{ss}$$

where: γ_{bs} and γ_{ss} are taken from the table below.

Values of γ_{bs} , γ_{ss} and γ_{ts}

Component Factors	γ_{bs}	γ_{ss}	γ_{ts}
Driven piles	1,3	1,3	1,3
Bored piles	1,6	1,3	1,5
Continuous flight auger (CFA) piles	1,45	1,3	1,4

In general, the load test only provides the pile load test versus settlement and time versus settlement diagrams, without distinction between point and shaft resistance. Therefore, it is often not possible to distinguish between partial factors for the assessment of the design value of base resistance and shaft resistance. Instead a partial factor on the ultimate characteristic pile resistance R_{cc} may be taken as the γ_{ts} values given in the table above.

D.5.3.16.2 Ultimate Bearing Resistance from Pile Driving Formulae

If pile formulae are used to assess the ultimate bearing resistance of individual compression piles in a foundation, the validity of the formulae shall have been demonstrated by previous experimental evidence of good performance or static load tests on the same type of pile, of similar length and cross-section, and in similar ground conditions.

Pile driving formulae shall only be used if the stratification of the ground has been determined.

In the design, the number of piles to be re-driven shall be specified. If re-driving gives lower results, these shall be used as basis for ultimate bearing resistance assessment. If re-driving gives higher results, these may be taken into consideration.

Re-driving should usually be carried out in silty soils, unless local comparable experience has shown this to be unnecessary.

D.5.3.16.3 Ultimate Bearing Resistance from Dynamic Load Tests

Dynamic load tests and their evaluation can be used to assess pile bearing resistance of individual compression piles. The validity of the evaluation shall have been demonstrated by previous evidence of acceptable performance or static load tests on the same pile type of similar length and cross-section and in similar soil conditions. The input energy level during the dynamic load testing shall be high enough to allow for an appropriate interpretation of the pile capacity at a correspondingly high enough strain level.

When deriving the ultimate characteristic bearing resistance R_{cc} from R_{cmd} values measured in two or several dynamic pile load tests, an allowance shall be made for the variability of the ground and the variability of the effect of pile installations a minimum, both conditions (a) and (b) of the table below shall be satisfied using the equation:

$$R_{cc} = R_{cmd} / \gamma_{nd}$$

Factors γ_{nd} to derive R_{cc}

Number of Load Tests	2	4	> 4
γ_{ns} on average R_{cms}	1,5	1,35	1,3
γ_{ns} on lowest R_{cms}	1,5	1,25	1,1

In order to derive the ultimate design bearing resistance, the characteristic value R_{cc} should be divided into components of base resistance R_{cbc} and shaft resistance R_{csc} such that:

$$R_{cc} = R_{cbc} + R_{csc}$$

The design bearing resistance R_{cd} shall be derived from:

$$R_{cd} = R_{cbc} / \gamma_{bd} + R_{csc} / \gamma_{sd}$$

Where γ_{bd} and γ_{sd} are taken from the table below:

Values of γ_{bd} , γ_{sd} and γ_{td}

Component Factors	γ_{bd}	γ_{sd}	γ_{td}
Driven piles	1,4	1,4	1,4
Bored piles	1,7	1,4	1,6

In case R_{cbc} and R_{csc} are not known the design bearing resistance R_{cd} is derived from:

$$R_{cd} = R_{cc}/\gamma_{td}$$

D.5.3.17 Piles in Tension

Pile load tests to determine the ultimate tensile resistance R_{tc} of an isolated pile shall be carried out in accordance with the international standards.

When deriving the ultimate characteristic resistance R_{tc} from values R_{tm} measured in one or several static pile load tests, an allowance shall be made for the variability of the ground and the variability of the effect of pile installation. As a minimum, both conditions (a) and (b) of the table below shall be satisfied using the equation:

$$R_{tc} = R_{tms} / \gamma_{nt}$$

Number of Load Tests	1	2	> 2
γ_{ns} on average R_{cms}	1,5	1,35	1,3
γ_{ns} on lowest R_{cms}	1,5	1,25	1,1

Normally when piles are loaded in tension, more than one pile shall be tested. In the case of a larger number of tension piles, at least 2 % shall be tested.

The design tensile resistance, R_{td} , shall be derived from:

$$R_{td} = R_{tc} / \gamma_m$$

Where $\gamma_m = 1,6$

D.5.3.18 Supervision of Construction

A pile installation plan shall be the basis for the construction work. The plan should give the following design information:

- the pile type with designation if standardised or technical approval otherwise;
- the location and inclination of each pile and tolerances on position;
- pile cross-section;
- pile length;
- number of piles;
- required pile load carrying capacity;
- pile toe level or the required penetration resistance;
- installation sequence;
- any other constraints on piling activities.

The installation of all piles shall be monitored and records shall be made at site and as the piles are installed. A record signed by the supervisor of the work and the pile manufacturer shall be kept for each pile.

The record for each pile shall include the following, where appropriate:

- pile type and installation equipment;
- pile number;
- pile cross-section, length and (for concrete piles) reinforcement;

- data and time of installation (including interruptions to the construction process);
- concrete mix, volume of concrete used and method of placing for cast-in situ piles;
- pumping pressures of the grout or concrete, internal and external diameters, pitch of screw and penetration per revolution (for continuous flight auger piles or other injection piles);
- for driven piles, the values of driving resistance measurements such as weight and drop or power rating of hammer, blow frequency and number of blows for at least the last 0,25 m penetration;
- the power take-off of vibrators (where used);
- the torque applied to the drilling motor (where used);
- for bored piles, the strata encountered in the borings and the condition of the base, if performance of the base is critical;
- obstructions encountered during piling;
- deviations of positions and directions and as-built elevations.

Records shall be kept for a period of at least 5 years after completion of the works. As built record plans shall be compiled after completion of the piling and kept with the Drawings.

If site observations or inspection of records reveal uncertainties with respect to the quality of installed piles, additional investigations shall be carried out to determine the as-built conditions of the piles and whether remedial measures are necessary. These investigations shall include either re-driving or pile integrity tests, in combination with soil mechanics field tests adjoining the suspected piles, and static pile load tests.

Tests shall be used to examine the integrity of piles for which the quality is sensitive in a reliable way.

Dynamic low strain integrity tests can be used for a global evaluation of piles that might have severe defects or that may have caused a serious loss of strength in the soil during construction. Since defects, like insufficient quality of concrete and thickness of concrete cover, affecting the long term performance of a pile, often cannot be found by dynamic tests, other tests such as sonic tests, vibration tests or coring may be needed in supervising the execution.

D.5.4 Permanent Steel (Sheet) Piles

D.5.4.1 Standards

In addition to the standards as listed the following standards or equivalent international standards shall apply:

- EN 1537 Grout anchors, design, execution and testing
- EN 12063 Sheet pile walls
- ENV 1997 Eurocode 7: geotechnical design

D.5.4.2 General

The work covered by this Part consists of furnishing and driving of steel (sheet) piles which are to be left in place so that they become a part of the permanent work, all in conformity with the requirements shown on the Contractor's approved shop drawings or in these specifications.

Application shall be retaining walls and pile foundation, only.

The Contractor shall carry out detailed design of these structures in accordance with the Contract Conditions and technical specifications and shall determine the type of foundation or supporting wall required, the number of piles and their working loads and the optimum arrangement of piles required for supporting the structures or walls.

Excavation and steel shall conform to the relevant Clauses of the technical specifications.

At least 21 days before the Contractor intends to commence piling work on the site the Contractor shall submit for the Engineer's approval full details of his proposed piling system including the type and dimensions of piles, reinforcement details and full details and full design and driving calculations. The details to be submitted shall include the Contractor's proposals for equipment, temporary works and construction methods.

No work on piling shall commence on the site until the Engineer's approval to the Contractor's proposal has been received.

D.5.4.3 Material Quality

The following strength classes shall apply:

- EN 10027-1
- EN 10027-2
- S275JO 1,0143
- S355JO 1,0553

D.5.4.4 Cutting and Welding

No cutting or welding of piles shall be carried out without prior written approval from the Engineer. All such cutting shall be carried out by means of oxyacetylene, oxypropane or other approved method. The remaining pile shall be of clean and even appearance with grinding tools being employed to remove splatter. Cut-offs shall be marked so that it is clear from which pile they came and after agreement from the Engineer will be disposed of in the pre-agreed manner. Cutting must be carried out in such a way as to prevent damage or distortion to adjacent piles. The finished level of the cut pile shall be within 20 mm of the theoretical level.

Only welders who are qualified to the international standards and have a proven record over the previous 6 months, or who have attained a similar standard, shall be employed on the works. Proof of welder proficiency shall be made available to the Engineer on request.

Defective welds shall be cut out and replaced. Where steel sheet piles are to be spliced by butt welding, the interlocks shall not be welded unless a sealing weld is required. Butt welding should only be carried out if the component ends have been matched together to ensure best possible fit.

D.5.4.4.1 Cutting Sheet Piles

When it is necessary to form holes in the sheet piles, they shall be drilled or burnt using a template, and subsequently dressed flush. The hole size shall be of sufficient clearance and will include allowance for bolt / tie coatings and inclination if not horizontal. All holes not required in the finished works which are not sealed in the pile cap or other such detail, shall be sealed by welding a plate of the same grade, of thickness not less than the plate thickness to the pile. The minimum plate overlap shall be 40 mm and the minimum continuous fillet weld size shall be 6 mm.

All holes shall be within a positional tolerance of ± 10 mm.

Holes formed as weep holes to avoid water build up behind the wall shall comply with the above details.

D.5.4.5 Retaining Walls

D.5.4.5.1 Design

Design of the retaining wall structure shall consider ultimate and serviceability limit states.

Ultimate limit states shall include instability of the structure as a whole including the soil mass, failure of the structure by bending or shear and excessive deformation of the wall or soil to the extent that adjacent structures or services are affected. Serviceability limit states shall include limited deformation of the structure and movement of the ground.

Surcharges and externally applied loads on each side of the wall: a minimum surcharge of 0,01 MPa on the retained side of the wall shall be used in design.

A minimum unplanned depth of excavation in front of the wall of 0,5 m or 10 % of the retained height of a cantilever or 10 % of the distance below the lowest support in a supported wall shall be included. In the case of a retaining structure with services buried in the passive zone, allowance shall be made for future excavation to replace or maintain the cables or pipes.

In permanent structures, the long term performance of the steel used must be considered.

Weep holes shall be provided behind the wall for drainage.

Sheet piles parts shall consider stresses caused by driving forces

The design shall consider full hydrostatic pressures behind the wall where this can occur.

D.5.4.5.2 Profiles

The steel sheet piles shall be LX or Larssen, in new condition and shall have an appropriate combined part modulus and mass to be submitted to the Engineer for approval.

The corners, junctions and special piles indicated on the working drawings shall be fabricated at the manufacturer's premises under workshop conditions or similar approved facility with quality assurance systems operative. All such work shall comply (within the tolerances) to the standard dimensions quoted by the manufacturer, or for non-standard fabrications to the approval of the Engineer.

If during the course of the works a requirement for extra fabricated piles occurs, the contractor shall submit to the Engineer for approval, the proposed type and method of manufacture. Piles of the same steel grade and part size as the neighbouring plain piles shall be used, unless otherwise approved.

All materials shall comply with the appropriate standards.

D.5.4.5.3 Tolerances

Width of single pile shall not deviate more than 2 % from nominal width.

Width of interlocked piles shall not deviate more than 3 % from nominal width of interlocked piles.

Maximal bow shall not exceed 0,2 % of total pile length.

Profile height may vary ± 4 mm for profiles heights below or equal 200 mm. Profile height may vary ± 5 mm for profiles heights above 200 mm.

Flange thickness may vary $\pm 0,5$ mm for flange thickness below or equal 8,5 mm. Flange thickness may vary ± 6 % for flange thickness above 8,5 mm.

Web thickness may vary - 0,5 mm for web thickness below or equal 8,5 mm. Web thickness may vary - 6 % for web thickness above 8,5 mm.

Profiles ends shall be cut plane and perpendicular to profile axis.

D.5.4.5.4 Coating

Steel sheet pile coating protection shall receive the following surface preparation and take the following form:

Sand blast clean to ISO 8501-1, grade 2, then application of high-build isocyanate cured, epoxy pitch (special coal tar pitch, modified with epoxy resins, cured with isocyanate adducts) in coat thicknesses of up to 400 µm or similar approved by the Engineer.

Due care and attention shall be given to the offloading, storing and installation of protected piles to prevent damage to coatings.

Any remedial work to coatings shall be carried out in accordance with the manufacturer's recommendations and to the satisfaction of the Engineer.

D.5.4.5.5 Capping

The top of the steel sheet pile shall be protected with a cap beam made of reinforced concrete, cross Part not less than 40 cm x 40 cm.

D.5.4.6 Ground Anchors

Pre-stressed ground anchors shall consist of high-strength bar or strand tendons grouted into an inclined hole drilled behind the face of the excavation. The ground anchors shall be installed and tensioned as the excavation progresses downward.

Wale beams shall be secured to each pair of piles with anchor bolts, washers and bearing plates. All splices, if welded or bolted, shall be at the fifth spacing between ground anchors and splices in wale beams and shall be staggered by a minimum distance of 5 m.

Tendons shall not be used for earthing purposes and will be protected against welding splash. Tendons shall be assembled with necessary taper washers, washers and bearing plates in accordance with the manufacturer's recommendations.

Tendons and fittings shall be protected against corrosion by appropriate and approved means.

D.5.4.6.1 Working Drawings

The Contractor shall submit to the Engineer working drawings and design submittals that shall include the following:

- Ground anchor schedule giving: - Ground anchor number - Ground anchor design load - Type and size of tendon - Minimum total anchor, bond, tendon bond, unbonded length
- Drawing of the ground anchor tendon and the corrosion protection system including details for the following: - Spacers, centralises, anchorage and trumpet and their location - Corrosion protection system for the bond and unbonded length and anchorage
- Certificates of Compliance for the following materials, if used. The certificate shall state that the materials or assemblies to be provided will fully comply with the requirements of the Contract, including: - Pre-stressing steel, strand or bar - Portland cement - Pre-stressing hardware - Bearing plates - Corrosion protection system

D.5.4.6.2 Tendon Bond Length Encapsulations

When the Drawings require the tendon bond length to be encapsulated to provide additional corrosion protection, the encapsulation shall be fabricated from corrugated HDPE with adequate wall thickness.

D.5.4.6.3 Heat Shrinkable Sleeves

Heat shrinkable sleeves shall be fabricated from a radiation crosslinked polyolefin tube internally coated with an adhesive sealant. Prior to shrinking, the tube shall have an adequate wall thickness.

D.5.4.6.4 Sheath

A sheath shall be used as part of the corrosion protection system for the unbonded length portion of the tendon. The sheath shall be fabricated from a PE tube pulled or pushed over the pre-stressing steel.

D.5.4.6.5 Bondbreaker

The bondbreaker shall be fabricated from a smooth plastic tube or pipe being resistant to chemical attack from aggressive environments, grout, or corrosion inhibiting compound; being resistant to ageing by ultraviolet light; being fabricated from material non detrimental to the tendon; being capable of withstanding abrasion, impact, and bending during handling and installation; and shall enable the tendon to elongate during testing and stressing; and shall allow the tendon to remain unbonded after lock-off.

D.5.4.6.6 Corrosion Inhibiting Compound

The corrosion inhibiting compound placed in either the free length or the trumpet areas shall be an organic compound (i.e. grease or wax) with appropriate polar moisture displacing, corrosion inhibiting additives and self-healing properties. The compound shall permanently stay viscous and be chemically stable and non-reactive with the pre-stressing steel, the sheathing material, and anchor grout.

D.5.4.6.7 Grout Tubes

Grout tubes shall have an adequate inside diameter to enable the grout to be pumped to the bottom of the drill hole. Grout tubes shall be strong enough to withstand the grouting pressure

D.5.4.6.8 Drilling

Drilling methods shall be left to the discretion of the Contractor, if not specified in the contract documents. The Contractor shall be responsible for using a drilling method to establish a stable hole of adequate dimensions, within the tolerances specified. Drilling methods may involve, amongst others, rotary, percussion, rotary / percussive or auger drilling; or percussive or vibratory driven casing.

Holes for anchors shall be drilled at the locations and to the length, inclination and diameter shown on the approved working Drawings. The drill bit or casing crown shall not be more than 3 mm smaller than the specified hole diameter. The ground anchor hole shall not be drilled in a location that requires the tendon to be bent in order to enable the bearing plate to be connected to the supported structure.

At the point of entry the ground anchor shall be installed within ± 3 degrees of inclination from horizontal shown on the approved working Drawings. At the point of entry the horizontal angle made by the ground anchor and the structure shall be within ± 3 degrees of a line drawn perpendicular to the plane of the structure unless otherwise shown on the approved working Drawings. The ground anchors shall not extend beyond the right-of-way or easement limits shown on the Contractor's approved shop drawings.

D.5.4.6.9 Tendon Insertion

Tendons shall be placed in accordance with the approved working Drawings and details and the recommendations of the tendon manufacturer or specialist anchor contractor. The tendon shall be inserted into the drill hole to the desired depth without difficulty. When the tendon cannot be completely inserted, the Contractor shall remove the tendon from the drill hole and clean or re-drill the hole to permit insertion. Partially inserted tendons shall not be driven or forced into the hole.

Each anchor tendon shall be inspected by Engineer during installation into the drill hole or casing. Damage to the corrosion protection system shall be repaired, or the tendon replaced if not repairable. Loose spacers or centralisers shall

be reconnected to prevent shifting during insertion. Damaged fusion-bonded epoxy coatings shall be repaired in accordance with the manufacture's recommendations.

The rate of placement of the tendon into the hole shall be controlled such that the sheathing, coating, and grout tubes are not damaged during installation of the tendon. Anchor tendons shall not be subjected to sharp bends.

D.5.4.6.10 Grouting

The Contractor shall use a neat cement grout or a sand-cement grout with Portland cement (CEM I) class CE I 32.5, 42.5 or 52.5 in accordance to EN 197. The cement shall not contain lumps or other indications of hydration. Admixtures, if used, shall be mixed in accordance with the manufacture's recommendation.

The grouting equipment shall produce a grout free of lumps and undispersed cement. A positive displacement grout pump shall be used. The pump shall be equipped with an appropriate pressure gauge to monitor pressures. The grouting equipment shall be sized to enable the grout to be pumped in one continuous operation. The mixer should be capable of continuously agitating the grout.

The grout shall be injected from the lowest point of the drill hole. The grout may be pumped through grout tubes, casings, hollow-stem-augers, or drill rods. The grout can be placed before or after insertion of the tendon. The quantity of the grout and the grout pressures shall be recorded. The grout pressures and grout takes shall be controlled to prevent excessive heave or fracturing.

After the tendon is installed, the drill hole may be filled in one continuous grouting operation except that pressure grouting shall not be used in the free length zone. The grout at the top of the drill hole shall not contact the back of the structure or the bottom of the trumpet.

If the ground anchor is installed in a fine-grained soil using drill holes larger than 15 cm in diameter, then the grout above the top of the bond length shall be placed after the ground anchor has been tested and stressed. The Engineer will allow the Contractor to grout the entire drill hole at the same time if the Contractor can demonstrate that their particular ground anchor system does not derive a significant portion of its load-carrying capacity from the soil above the bond length portion of the ground anchor.

The grout tube may remain in the hole on completion of grouting if the tube is filled with grout.

After grouting, the tendon shall not be loaded for a minimum of 3 days.

D.5.4.6.11 Anchorage Installation

The anchor bearing plate and the anchor head or nut shall be installed perpendicular to the tendon, within ± 3 degrees and centred on the bearing plate, without bending or kinking of the pre-stressing steel elements. Wedge holes and wedges shall be free of rust, grout and dirt.

The stressing tail shall be cleaned and protected from damage until final testing and lock-off. After the anchor has been accepted by the Engineer, the stress tail shall be cut to its final length according to the tendon manufacturer's recommendations.

The corrosion protection surrounding the unbonded length of the tendon shall extend up beyond the bottom seal of the trumpet or 10 cm into the trumpet if no trumpet seal is provided. If the protection does not extend beyond the seal or sufficiently far enough into the trumpet, the Contractor shall extend the corrosion protection or lengthen the trumpet.

The corrosion protection surrounding the unbonded length of the tendon shall not contact the bearing plate or the anchor head during testing and stressing. If the protection is too long, the Contractor shall trim the corrosion protection to prevent contact.

D.5.4.6.12 Corrosion Protection

The corrosion protection systems shall be designed and constructed to provide reliable ground anchors for temporary and permanent structures.

All stressing anchorages permanently exposed to the atmosphere shall receive a grout-filled cover, except, for re-stressable anchorages, a corrosion inhibiting compound must be used. Stressing anchorages encased in concrete at least 5 cm thick do not require a cover.

The trumpet shall be sealed to the bearing plate and shall overlap the unbonded length corrosion protection by at least 10 cm. The trumpet shall be long enough to accommodate movements of the structure and the tendon during testing and stressing.

The trumpet shall be completely filled with grout, except re-stressable anchorages must use corrosion inhibiting compounds. Compounds may be placed any time during construction. Compound filled trumpets shall have a permanent seal between the trumpet and the unbonded length corrosion protection. Grout must be placed after the ground anchor has been tested and stressed to the lock-off load. Trumpets filled with grout shall have either a temporary seal between the trumpet and the unbonded length corrosion protection or the trumpet shall fit tightly over the unbonded length corrosion protection for a minimum of 10 cm.

Corrosion protection of the unbonded length is described above.

D.5.4.6.13 Testing - General

Each ground anchor shall be tested. No load greater than 10 % of the design load can be applied to the ground anchor prior to testing. The maximum test load shall be no less than 1,33 times the design load and shall not exceed 80 % of the specified minimum ultimate tensile strength of the pre-stressing steel of the tendon. The test load shall be simultaneously applied to the entire tendon. Stressing of single-element tendons shall not be permitted.

The testing equipment shall consist of:

- A dial or vernier scale capable of measuring accurately enough shall be used to measure the ground anchor movement;
- A hydraulic jack and pump shall be used to apply the test load. The jack and two calibrated pressure gauges shall be used to measure the applied load. The jack and all pressure gauges shall be calibrated by an independent firm as a unit. Testing cannot commence until the Engineer has approved the calibration;
- An electrical resistance load cell and readout to be used when performing an extended creep test;
- The stressing equipment shall be placed over the ground anchor tendon in such a manner that the jack, bearing plates, load cells and stressing anchorage are axially aligned with the tendon and the tendon is centred within the equipment;
- The stressing equipment, the sequence of stressing and the procedure to be used for each stressing operation shall be determined at the planning stage of the project. The equipment shall be used strictly in accordance with the manufacturer's operating instructions;
- Stressing equipment shall preferably be capable of stressing the whole tendon in one stroke to the specified test load and the equipment shall be capable of stressing the tendon to the maximum specified test load within 75 % of the rated capacity. The pump shall be capable of applying each load increment in less than 60 seconds;
- The equipment shall permit the tendon to be stressed in increments so that the load in the tendon can be raised or lowered in accordance with the test specifications, and allow the anchor to be lift-off tested to confirm the lock off load;

- Stressing equipment shall have been calibrated, within an accuracy of $\pm 2\%$. The calibration certificate and graph shall be available on site at all times. Dial gauges shall bear on the pulling head of the jack and their stems shall be coaxial with the tendon direction. The gauges shall be supported on an independent, fixed frame, such as a tripod, which will not move as a result of stressing or other construction activities during the operation.

Prior to setting the dial gauges, the Alignment Load (AL) shall be accurately placed on the tendon. The magnitude of the AL depends on the type and length of the tendon.

Re-gripping of strands, which would cause overlap wedge bites, or wedge bites on the tendon below the anchor head, shall be avoided.

Stressing and testing of multiple element tendons with single element jacks is not permitted.

Stressing shall not begin until the grout has reached adequate strength.

The anchor testing program shall consist of two parts, namely, performance tests and proof tests.

Anchor installations for performance testing within each area shall be as directed by the owner's representative. One anchor per wall area shall be tested in accordance with the performance test procedures. These anchors should be located in the area of soil borings if possible. These anchors are to be installed, tested, and approved by the owner's representative prior to the installation of production anchors within that area. All anchors which are performance tested shall be used as production anchors and incorporated into the retention structure.

Upon completion and approval of the performance tests in an area, the installation of production anchors may proceed.

Proof tests shall be performed on all production anchors which are not performance tested. Proof tests results are subject to the approval of the owner's representative.

D.5.4.6.14 Performance Test Procedures

Two production anchors shall be performance tested. These tests should be located near soil borings if feasible.

The anchors which are performance tested may be completely unloaded prior to adjusting to the lock-off load, if so warranted by the construction sequence. Final loading to the lock-off load does not require further movement readings.

Anchors shall be performance tested in accordance with the following schedule:

Cyclical load increments (% DL / 100)

	AL	AL	AL	AL
0,25 DL	0,25 DL	0,25 DL	0,25 DL	0,25 DL
0,50 DL	0,50 DL	0,50 DL	0,50 DL	0,50 DL
		0,75 DL	0,75 DL	0,75 DL
			1,00 DL	1,00 DL

AL = Alignment Load (10%-15% DL)

DL = Design (Working) Load

The load shall be maintained at each load increment for a sufficient period of time to allow for accurate movement readings to be recorded. This applies to all load increments except the 1,25 DL increment.

The 1,25 DL load increment shall be held for 10 minutes. The 10 minute observation period shall commence as soon as the 1,25 DL load is applied to the anchor. Movements shall be recorded at 0,5, 1, 2, 3, 4, 5, 6, and 10 minutes. If the anchor movement between the 1 minute and 10 minute readings exceeds 1 mm, then the 1,25 DL test load shall be maintained for an additional 20 minutes. Movements shall be recorded at 15, 20, 25, and 30 minutes. If the acceptance

criteria given below is not satisfied, then the anchor test shall be continued for an additional 30 minutes. Movements shall be recorded at 45 and 60 minutes. If the acceptance criteria is not satisfied after this extended observation period, then the contractor shall exercise one of the options as referenced below.

Throughout the 1,25 DL observation period, the load shall be held constant by adjusting the hydraulic pressure. Care must be taken so as not to exceed the 1,25 DL test load.

D.5.4.6.15 Proof Test Procedures

All anchors which are not performance tested shall be proof tested.

Anchors which are proof tested may be completely unloaded prior to adjusting to the lock-off load, if so warranted by the construction sequence. Final loading to the lock-off load does not require further movement readings.

Anchors shall be proof tested in accordance with the following schedule:

Loading Schedule

Observation	
Increment	Period
[% DL / 100]	[min]
AL	0,0
0,25 DL	2,0
0,50 DL	2,0
0,75 DL	2,0
1,00 DL	2,0

AL = Alignment Load (10 % - 15 % DL)

DL = Design (Working) Load

The load increments from AL to 1,0 DL shall be maintained for a period not to exceed 2 minutes. The 2 minute observation period shall begin when the pump begins to load the anchor to the next load increment. Movement readings shall be taken at the end of the two minute observation period. This does not apply to the 5 minute observation period at 1,25 DL test load.

The 1,25 DL test load shall be maintained for 5 minutes. This 5 minute observation period shall commence as soon as the 1,25 DL is applied to the anchor. Movement readings shall be recorded at 0,5, 1, 2, 3, 4, and 5 minutes. If the movement between the 0,5 and 5 minute reading exceeds 1 mm, then the 1,25 DL test load shall be maintained for an additional 5 minutes. Movement readings shall be recorded at 6 and 10 minutes. If the acceptance criteria given below is not satisfied, then the anchor test shall be continued for an additional 20 minutes. Movement readings shall be recorded at 15, 20, 25, and 30 minutes. If the acceptance criteria given below is not satisfied after this extended observation period, then the contractor shall exercise one of the options as referenced below.

Throughout the 1,25 DL observation period, the load shall be held constant by adjusting the hydraulic pressure. Care must be taken so as not to exceed the 1,25 test load.

D.5.4.6.16 Acceptance Criteria

The net movement for the performance and proof tests shall not exceed 3 mm during the final log cycle of time (examples, 3-min. to 30-min. for performance tests; 1-min. to 10-min. for proof tests).

If the above criteria is exceeded, then the test shall be continued for an extended period of time as defined for the performance test and for the proof test. If the final log cycle of time movement at the end of the extended observation period exceeds 0,12 then the contractor shall have the following options:

- a) Extend the observation period for an additional 60 minutes for the performance test with movement readings taken at 80, 90, 100, and 120 minutes. Extend the observation period for an additional 30 minutes if the proof test is involved with movement readings taken at 45 and 60 minutes. The net movement shall not exceed 3 mm during the final log cycle of time.
- b) Install the anchor deeper so as to increase its average installation torque, provided that the maximum torque capacity of the anchor will not be exceeded. This anchor shall be proof tested.
- c) Remove the anchor and reinstall an anchor with larger diameter and/or additional helices. If this anchor is reinstalled at the same location, then the last helix of this reinstalled anchor shall penetrate at least 1,5 m beyond the length of the original anchor. This anchor shall be proof tested.
- d) Reduce the design load of the anchor. This anchor shall be performance tested at the reduced design load. This option will require one or two additional anchors be installed adjacent to this reduced design load anchor. The number of additional anchors to be installed is a function of the reduced design load. Adjacent anchor(s) shall be installed at least 1,2 m from the reduced design load anchor. Design loads on adjacent anchor(s) shall be adjusted accordingly based on the revised horizontal spacing.

D.5.5 Steel Pile Foundations

D.5.5.1 Profiles

Bearing piles shall be H-Part bearing piles, Larssen box piles or tubular piles.

D.5.5.2 Design, Testing, Driving

For design of piles, preliminary test of piles, lengths of piles, sequence for constructions, and driving piles the relevant Standards shall apply.

D.5.5.3 Repair and Lengthening

In preparation for repairing the head of a pile the profile shall be cut off plane and perpendicular to the profile axis.

If the pile is to be subjected to further driving or the pile has been completely driven but the end is below cut-off level the new profile part shall be welded onto the driven profile Part.

D.5.5.4 Piling

D.5.5.4.1 Method Statement

Before the commencement of any piling works, the contractor shall submit 3 weeks before starting the works to the Engineer for approval a safety policy and a method statement which shall include the following information:

- Program of the works detailing sequence and timing of individual portions of the works.
- Maximum proposed lead at any stage of driving between a pile and its neighbour and the limitations of same if hard driving is encountered.
- The height, spacing, stability and type of piling guidance system and the number of piles in each panel if applicable.
- Full details of installation plant to be utilised including manufacturers information, proof of servicing/recent upkeep and assessment of actual input energy to the piles and a definition of driving refusal for each type of plant proposed.

- Proposed phasing of excavation/filling operations such that designed stresses in the piles and frames/supports are not exceeded.
- Contingency plan in the event of encountering obstructions or reaching driving refusal to minimise disruption/delay especially when using pitch and drive methods.
- Details of the envisaged noise production and the Contractor's intended method of noise minimisation.
- Details of the estimated vibration levels created by the works and the Contractor's intended method of noise minimisation.

D.5.5.4.2 Handling

All piles shall be stacked in accordance with the manufacturer's recommendations.

The Contractor shall ensure that operations involving loading, transporting, offloading, handling, stacking and pitching the piles, are carried out in such a manner as to prevent damage to the piles or their coating.

Any damage that does occur shall be drawn to the attention of the Engineer and the Contractor shall submit his proposals for remedial works for approval prior to commencement. The Engineer's approval of the completed remedial measures will be required before inclusion into the structure can take place.

Holes shall not be burnt / drilled nor lifting brackets welded to the sheet piles without the prior approval of the Engineer. All such modification shall be made good after use.

Wherever possible the same pile parts, lengths and steel grades shall be stored in separate stacks clearly marked / colour coded to avoid errors in placement.

D.5.5.4.3 Pitching & Driving

The selection of the driving and extracting plant shall be made having due regard to the ground conditions and pile type.

The Engineer shall be notified of the contractor's intention to pitch and drive piles at least 24 hours prior to commencement of the installation works. Prior to interlocking sheet piles the contractor shall ensure that the locks are undamaged clean and free from deleterious materials.

Pitch and drive techniques shall be permitted if the following criteria are met:

- The rig has sufficient height to adequately support the entire pile during driving;
- The driving will be relatively easy, without hard bands or obstructions which would dictate the requirement for full support afforded by panel driving techniques;
- The Contractor can satisfy the Engineer that the sheet pile structure can be built to conform with the specified tolerances for verticality and alignment.

In all cases the piles shall be guided and held in position during pitching and driving. All piles shall be fully interlocked without exception. Overlapping of piles will not be accepted as a substitute for interlocking piles.

Taper piles shall not be introduced to correct piles which have developed a lean, unless the approval of the Engineer is first obtained.

Piles which reach refusal before achieving the design penetration shall not be cut off without the approval of the Engineer. In difficult driving conditions a lead in excess of 1 m shall not be allowed to develop between the toe level of the pile being driven and the level of its neighbouring pile.

The contractor shall do all within his power / experience to avoid driving damage or declutching. The Engineer shall be notified immediately if any of these occur.

Percussive piling hammers shall be either freely suspended in which case they will have suitable leg guides / inserts in sound working order, or leader mounted in which case the leader must be of suitable rigidity and strength to keep the hammer stable during driving and moving operations. In all cases the hammer shall be held in position over the pile such that each blow is directed axially down the centreline of the pile / pair. (When driving high modulus units the centreline of the hammer blow shall be positioned as close to the centreline of the combined unit or between that position and the centreline of the beam unit).

The anvil block shall be of sufficient plan area to cover at least 90 % of the pile or piles being driven and of sufficient thickness to adequately transfer the heaviest hammer blow evenly to the pile heads. The anvil shall be flat and level, without substantial wear such that the blow is transferred axially and distributed evenly over the pile head.

Where sheet piles are driven to a set to indicate vertical load carrying capacity this shall always be calibrated by maintained load testing on a representative sample of the piles. The set shall be recorded with a hammer of well defined input energy such as a gravity drop hammer or a hydraulic drop hammer. Where it is unavoidable to use hammers of less certain input energy, i.e. air hammers and diesel hammers, then the maximum losses must be used in the set calculation i.e. assuming approximately 30 % hammer efficiency.

D.5.5.4.4 Driving Tolerances

The following tolerances are suitable for general site practice for permanent structures. However more lenient limits may be applied if difficult driving conditions are encountered i.e. obstructions or the works are only temporary:

- Deviation perpendicular to theoretical line ± 50 mm;
- Deviation of verticality normal to and along the line of the piles, 1 in 100;
- Top of finished pile level ± 20 mm.

Deviation from these tolerances will not be acceptable without written agreement from the Engineer. Forcible correction will not be permitted.

The above tolerances are included for guidance purposes only and should be altered depending on site specific requirements

D.5.5.4.5 Driving Records

The Contractor shall keep complete and accurate piling records. Two signed copies of these records shall be submitted to the Engineer not more than 48 hours from the date of the works detailed therein. The pile records shall always be submitted with sufficient time for the Engineer's approval prior to the piles becoming inaccessible due to further operations.

The records shall contain the following information:

- Pile reference number (correlated to previously accepted works general arrangement drawing showing each pile position and reference).
- Pile type and steel grade.
- Pile length.
- Commencing surface level and final toe level.
- Depth driven, type of construction plant and times and dates when piles were driven.
- Where required the number of blows to drive each 250 mm over the last 2,5 m shall be recorded.
- Comments regarding unusual/ unexpected driving conditions (both harder, e.g. obstructions, or easier, i.e. increased penetration rates) should be included.

- Where changes in the pile length have occurred due to lengthening or cutting, all relevant information including off-cut length or extension length, reason for change and on what authority the change was made shall be included.

D.6. Ground Treatment

D.6.1 General

Any ground treatment proposed by the Contractor to improve the bearing capacity and/or settlement characteristic of the soil must be supported by a full method statement and design calculations with a statement of the minimum performance to be achieved.

In the selection of the ground improvement method, the time limitations of the Contract shall be taken into consideration. The method is subject to the approval of the Engineer. Where directed by the Engineer, the Contractor shall carry out a field trial of the proposed treatment to demonstrate that it meets the stated performance criteria.

All in-situ verification of ground improvements shall be made by CPT or SPT test after ground improvement works.

D.6.2 Soil Replacement

Soil replacement involves excavating the soil that needs to be improved and replacing it. Excavated soil shall be replaced with compacted granular soil (sand and gravel) with suitable properties for the proposed application.

Methods and material for soil replacement shall be approved by the Engineer.

D.6.3 Admixture Stabilisation

Admixture stabilisation consists of mixing or injecting admixtures, such as cement, lime, fly ash or bentonite into a soil, to improve its properties. Admixtures can be used to increase the strength, decrease the permeability or improve the workability of a soil. Admixtures can fill voids, bind particles, or break down soil particles and form cement. The general process of admixture stabilisation consists of (1) excavating and breaking up the soil, (2) adding the stabiliser and water, if necessary, (3) mixing thoroughly, and (4) compacting the soil and allowing it to cure.

During stabilisation of soils with admixtures, the most important observations are the amount of admixtures and water mixed into the soil, the amount of mixing performed and the amount of compactive effort used on the fill. The moisture content and density of the fill can be determined in the field. The curing time and conditions should also be recorded. Samples should be taken for laboratory testing.

Method of admixture stabilisation shall be approved by the Engineer.

D.6.4 Jet Grout Columns

The Contractor is required to test several jet grout column sections prior to construction, to determine the geometry and quality of treated material that can be obtained.

For assessing the geometry, excavation of coring shall be made. Wet grab samples shall be taken for strength and permeability testing. If piezometers are installed for later hydraulic conductivity measurements, the construction details of the piezometers shall be recorded.

During construction, it shall be monitored and the Contractor is required to note if the grouting parameters and materials are consistent with the approved test section. The ability to erode the soil with the jets is an important factor in

successful jet grouting. There shall be a continuous flow of spoils to the ground surface during jetting. If there is no spoil return, it is possible that hydrofracturing is occurring. The rate of rotation and removal of the grout pipe and the rate of material consumption shall be monitored.

Method of jet grouting shall be approved by the Engineer

D.6.5 Prefabricated vertical Drains (wick drains – strip drains)

The Contractor is required to prepare a method statement for preloading with wick drains based on the geotechnical report. This method statement shall include the following data:

1. Materials;
2. Monitoring equipment;
3. Spacing and depth of wick drains (drain layout drawings);
4. Spacing and depth of settlement gauges (monitoring system layout drawings);
5. Height of pre-loading fill;
6. Time required for achieving design settlements;
7. Record keeping
8. Expected vertical displacements (swell / settlements) during trial loading, preloading, excavation for foundations and in long term (for centres and edges of foundations).

First stage in the application of the prefabricated drain, shall be removing the topsoil, installing surface settlements plates, laying the separation geotextile and placing the drainage layer according to the thickness stated in the Method Statement and extend this drainage layer to the drainage trenches around.

Later, the vertical drain locations shall be marked. Prefabricated wick drains shall be installed down to the depth stated in the Method Statement using a special steel mandrel mounted on the service crane. The mandrel shall be pushed into the soil using a vibratory hammer.

Wick drains shall be placed at constant load and high speed in order to avoid disturbance of soil. Vertical misalignments shall be avoided by checking with a water balance.

A drainage ditch shall be excavated around the perimeter of the wick drain fields. This drainage trench will collect the discharge coming from the granular drainage layer over the wick drain field.

Finally, another separation geotextile shall be laid over the granular drainage layer over the wick drain field. Before any preloading fill material is placed, settlement columns and magnetic extensometer shall be installed according to the Method Statement, in order to find out the future settlements. The settlements shall be measured and recorded until the displacements have reached the desired level.

Preloading fill materials shall be laid around the perimeter of the large structures and the base of the fills shall be extended at least 4 meters outside the structure's borders. Then the fill will be placed with 1H : 1V side slope, to a maximum height of 4 meters.

Fill material will be laid uniformly in 200 - 300 mm thick layers and spread uniformly. No compaction tests are required and compaction will be achieved by the truck traffic over the fill construction. Therefore it is mandatory to place the fill homogeneously and uniformly.

Surface settlement measuring plates will be buried in natural ground at the preloading area and these will be protected and extended as described in the Method Statement.

A working platform shall be formed to support drain installation equipment. Drainage payer may be used for this purpose; however, thickness of the drainage layer may need to be increased to support the equipment as required.

The drain capacity could be the limiting factor in cases where PV drains are designed for sites where there are deep compressible layers with surcharge loading. When PV drains are designed to function near their maximum capacity, the installation shall be monitored carefully. Before using wick drains below a depth of 45 m, a specialist shall be consulted.

Wick drains shall be composed of two parts: inner core and filter material. These may be manufactured as a single material or the filter may be wrapped around the core, and overlapped to keep the core closed inside.

Wick drains shall be 100 mm wide, 6 mm thick polyester (PES) or polypropylene (PP), or similar, with the approval of the Engineer.

Wick drains shall be flexible, capable of being rolled to a 300 mm diamtere drum without damage. The wick drain must be strong enough so it will not break, tear or lose ist drainage properties during installation. The core of the drain shall resist crushing or formation of kinks when bent.

The position of the wick drains shall be at most 100 mm away from the coordinates shown on the drain layout drawings.

Vertical deviation of the drains shall be at most 1 Horizontal in 50 Vertical.

Wick drains shall be cut at leaast 150 mm above the working platform.

Daily reports shall be written for the drains installed. A copy of these reports shall be presented to the Engineer within two days after installation. The records shall include:

- Date;
- Reference area and grit for each drain;
- Depth of installation of each drain ;
- Obstacles and delays;
- Reading of the installed instruments.

Any unexpected conditions experienced and reported will be briefly mentioned in these records.

After all field works are completed, two (2) copies of the Final Report will be presented to the Engineer within two (2) weeks after removing the preloading fill.

Method of preloading with wick drains shall be approved by the Engineer.

D.6.6 Flood Protection

D.6.6.1 General

The main aims of the flood protection works are:

- To avoid flooding water into the facility, protecting in this way its structural stability;
- To protect the building and roads of the facility site from erosion caused by flooding.

The flood protection works of the site consist in the following:

- Ditches for the protection of the facilities;
- Ditches for the protection of internal road network;

- Well for the drainage of the ditches and sewers.

The ditches aim at interception and transporting the rainwater from the outside basins and internal sub-basins. The flooding protection will be succeeded via perimetric insulated ditches outflow wells through which the water will be lead to the natural recipient.

The hydrologic calculations should be made for a minimum return period of 20 years. A safety factor has to be adopted for the maximum discharge that the ditches can convey.

It is clearly stated that rainwater that will occur throughout the facility will be collected separately from washing and similar wastewaters.

If new construction of structures or facilities are to be located in a floodplan, accepted flood proofing and other flood protection measures shall be applied to new construction or rehabilitation. To achieve flood protection, Contractors shall, wherever practicable, elevate structures above the base flood level rather than filling in land.

D.6.6.2 Earth Dikes

Dikes shall be high enough to prevent the 100-year flood. Existing dikes at the plant area shall also be investigated. These shall be reshaped or rebuilt where necessary and repaired in areas of the dikes where erosion has occurred.

Design requirements for earth dikes include:

- Preconstruction surveys required for design;
- Soil sampling and soil tests for dike embankments fill borrow areas;
- Design of local drainage improvements (including culverts with flap gates and/or manual control gates).

D.6.6.3 Mortared Stone Walls and Slabs

Mortared stone walls and slabs shall be built at locations shown on the Contractor's approved shop drawings or specified by the Engineer, with the sections and stone sizes shown on the details or specified by the Engineer.

Before the stones are placed, ground surface shall be arranged smooth and parallel to the finished surface considering the stone thickness and wall slope. Wall thickness shown on the Contractor's approved shop drawings or specified by the Engineer must be achieved with a single stone layer, and two stone layers on top of each other will not be accepted.

The void between the stones shall be filled completely with mortar and stones shall be hammered after laying to get a strong bond between stones.

Larger stones shall be used at the edges of the stone surfaces, especially at the skirts of sloped surfaces. Stones shall be laid from bottom to the top. Mortar, cement and water shall be in accordance with the technical specifications regarding concrete and steel works.

D.7. Concrete Works

D.7.1 General

D.7.1.1 Scope

This section covers the technical requirements for the concrete Works as specified in the Contract including the supply of materials, mixing of concrete, formwork, reinforcement, placing, compaction, and curing of concrete...etc.

D.7.1.2 Standards and Rules

The Contractor shall carry out the works described in this Section in accordance with the appropriate standards ISO, EN or equivalent international standards.

The main standards include, but shall not be limited by, the following:

- ISO 22965 Concrete;
- ISO 19595 Natural aggregates for concrete;
- ISO 22966 Execution of concrete structures;
- ISO 16311 Maintenance and repair of concrete structures;
- ISO 20290 Aggregates for concrete — Test methods for mechanical and physical properties;
- ISO 19596 Admixtures for concrete;
- ISO 1920 Testing of concrete;
- EN 206 Concrete - Specification, performance, production and conformity;
- EN 934-2 Admixture for concrete, mortar and grout;
- EN 12350 Testing fresh concrete. Slump test;
- EN 1992-2 Design of concrete structures. Concrete bridges;
- EN 13791 Assessment of in-situ compressive strength in structures and pre-cast concrete components;
- EN 1008 Mixing water for concrete;
- EN 10080 Steel for the reinforcement of concrete;

D.7.1.3 Concrete Specifications

Concrete specifications shall be in accordance with ISO 22965 and EN 206 . The Contractor shall submit to the Engineer for approval the proposed concrete specifications for the various concrete works. This includes in particular:

- compressive strength class;
- exposure classes;
- D_{upper} and D_{lower} .

The concrete specification should cover all concrete strength classes that are represented for all concrete structures from the project documentation except for prefabricated elements. For prefabricated concrete elements and structures, the Contractor shall obtain evidence of the quality of materials and products from the manufacturer and submit them to the Engineer for approval before the delivery of concrete products.

D.7.1.4 Organisation of Concrete Production

Upon Contract commencement, the Contractor shall submit for approval of the Engineer a method statement detailing his proposal for the organisation of concreting activities at the Site. A certified concrete plant should preferably be located on Site or have concrete delivered from a concrete plant.

The method statement shall at least include:

- Plant proposed and layout of the production facility;
- Proposed method of organisation of the production plant;
- Quality control procedures for concrete and concrete production;

- Method of transport including heat protection and placing of concrete;
- Striking times for formwork and procedure for temporary support of beams and slabs;
- Curing of concrete and ways to assure an optimum curing.

D.7.1.5 Aggregate Samples

Before work on trial mixes is commenced, the Contractor shall submit for approval 50 kg samples of each aggregate which he proposes to use.

The source of each aggregate shall be clearly marked on the container of each sample.

At the same time certified test results, demonstrating compliance with relevant quality standards such as ISO 20290 and EN 12620 shall be submitted.

Samples approved by the Engineer shall be preserved at Site for reference.

D.7.1.6 Records of Concreting

The Contractor shall keep accurate and up to date records of concreting for each day when sections of the works were concreted showing at least:

- Date, time, weather and temperature;
- Results of all concrete tests including identification for which parts of works the sampled material are representative;
- Number of batches produced, weight and kind of cement used, volume of concrete placed, number of batches wasted or rejected;
- Class of concrete, volume of concrete placed and number of batches used for each location.

The laboratory where concrete tests have to be carried out shall be approved by the Engineer and be accessible at any time. The laboratory shall preferably be placed on Site.

D.7.1.7 Concrete Mixes

At the commencement of the works, the Contractor shall be obliged to submit valid laboratory recipes for concrete mixtures for each class of concrete which shall be required for use in the works and shall submit full details of the mix designs to the Engineer for approval (also see D.7.3.7). Each mix design shall be according to the requirements of the respective specification (see D.7.3.1).

D.7.1.8 Construction Joints and Lifts

The Contractor shall submit to the Engineer, not later than 3 weeks prior to the commencement of concreting, drawings showing his proposals for placing concrete and the position of all construction joints which have to be located as not to impair the strength of the structure.

No concreting shall start until the Engineer has approved concrete placing and the position and form of construction joints.

Rebates, keys or notches shall be formed and adequate water stops inserted as the Engineer may require.

The position of construction joints and the size of formwork panels shall be so coordinated that where possible the line of any construction joint coincides with the line of a formwork joint and that in any case all construction joint lines and formwork joint lines appear as a regular and uniform series.

For all exposed horizontal joints and purposely-inclined joints, a uniform joint shall be formed with a batten of approved dimensions to give a straight and neat joint line.

D.7.2 Materials

D.7.2.1 Cement

All cement used on the Work shall be standard brand Portland cement from a single approved source conforming to the requirements of Portland cement class CEM I 32.5 R or class CEM I 32.5 HS in accordance to ISO 679, ISO 9597, EN 196 and EN 197 or equivalent.

Cement used in the works for structural parts underground or in contact with wastewater shall be sulphate-resisting Portland cement, class CEM III 32.5 N SR-LH.

The source of cement shall not be changed without prior approval of the Engineer.

Samples of cement, water and fine and coarse aggregates called for in the foregoing sections shall be provided to the Engineer. Cube tests shall be completed before work is due to start.

Cement has to be delivered to the Site in the original sealed and branded bags.

No cement shall be used which has been manufactured 6 months prior to its proposed use on Site or which has been in storage for more than 3 months, whichever is shorter.

The Contractor shall provide from each consignment of cement delivered to the Site such samples as the Engineer may require. Cement on the construction site is used only for making small amounts of concrete. Only concrete produced at concrete plants is used for concreting facilities on the pipeline route.

D.7.2.2 Storage of Cement

Immediately upon arrival on Site, the cement shall be stored in silos or in dry, weather tight and properly ventilated structures with adequate provisions to prevent absorption of moisture.

All storage facilities shall be subject to the approval by the Engineer and shall be such as to permit easy access for inspection and identification.

Each consignment of cement shall be kept separately and the Contractor shall use the consignments in the order in which they are received.

D.7.2.3 Aggregates

Aggregates shall be hard, durable and clean and shall not contain deleterious material in such form or quantity as to adversely affect the strength of concrete. The aggregates shall be obtained from an approved source, shall be washed clean and shall conform to the requirements of ISO 20290, EN 206 and EN 12350.

The aggregates to be supplied shall not give rise to any alkaline reaction with the cement, weathered silica or carbonate. In addition, the soluble chloride and sulphate content of the aggregates shall be such that the concrete mix as a whole complies with the specified limits of the salt content. For limits of soluble chloride and sulphate contents see D.7.3.4.

Proof of chloride and sulphate contents for aggregates shall be given by certified / recorded history of aggregate testing, or certificates from an approved concrete supplier.

If no proof for this can be given, tests for chlorides and for potential alkaline reaction may be carried out by the Contractor upon the Engineer's request.

D.7.2.4 Storage of Aggregates

The Contractor shall provide storage facilities for aggregates which shall comply with following requirements:

- Each nominal size of coarse and fine aggregates shall be kept separate at all time;
- Contamination of aggregates by the ground or other foreign matter shall be prevented effectively at all times;
- Each heap of aggregate shall be capable of draining freely;
- Aggregates are kept as cool as possible by shading and provision of water sprinkling if required.

The Contractor shall ensure that graded coarse aggregate is not segregated during tipping, storing and removal from storage.

Fine aggregate shall not be used unless approved by the Engineer, and it is conditioned to acceptable and uniform moisture content. If necessary to meet this requirement, the Contractor shall protect the heaps against weather, and shall condition fine aggregate in accordance with the applicable standards and approved procedures. Storage and use of aggregates for concrete preparation on the construction site is used only for minor concreting, other quantities of concrete must be delivered from the concrete plant.

D.7.2.5 Water

Water for washing aggregates and for mixing of concrete shall be in accordance with ISO 22965 and EN 206, and shall be clean and free from objectionable quantities of organic matter, alkali, salts and other impurities.

The water shall enter the mixer at the lowest possible temperature and shall not exceed 30° C. The chloride content should be less than 6%.

During the execution of works, the Contractor shall ensure that sufficient quantities of water for production and curing of concrete are available on Site at all times.

D.7.2.6 Admixtures

Admixtures shall be used to improve the characteristics of reinforced concrete structures (e.g. watertightness of pumping station water chambers) in cases where required by the design.

By instructions from the Engineer, or at the request of the Contractor and approved by the Engineer, an admixture may be added to the concrete in order to control the set, to effect water reduction and to increase workability. The admixtures shall be approved by the Engineer.

Such admixture shall not contain calcium chloride and it shall be used in accordance to the manufacturer's instructions and be in accordance with ISO 19596.

D.7.3 Concrete

D.7.3.1 Proportioning of Concrete Materials

Concrete shall be composed of cement, aggregates, water and, when unavoidable, of admixtures. These materials shall be of the qualities specified and their proportioning shall be determined in accordance with all requirements imposed by ISO 22965 or EN 206 and be subject to the approval of the Engineer.

Concrete preparation mixtures must be prepared in accordance with recipes developed by authorised laboratories and in accordance with applicable norms and standards.

In general, the mix shall be designed to produce concrete capable to be placed so as to obtain maximum density and strength and smoothness to the surface.

The proportions may be changed if instructed or approved by the Engineer.

D.7.3.2 Impermeable Concrete

All concrete for underground works (e.g. manholes,) shall be of impermeable concrete according to ISO 22965 or EN 206.

D.7.3.3 Water-Cement Ratio and Compressive Strength

The minimum compressive strength and cement content shall be not less than required in the appropriate approved international Standards.

If necessary to obtain the required strength, the Engineer may instruct that the cement content of any class to be increased over the quantity specified in the standard.

The maximum ratio of water and cement for minor concreting on the construction site shall not exceed 55 l of water per 100 kg of cement. For larger quantities of concrete, the concrete mix shall be prepared according to the valid concrete production recipe.

D.7.3.4 Limits of Salt Contents

All concrete mixes shall contain less than 0.6 % total chlorides (as chloride ions) and less than 4.0 % total acid soluble sulphate (as sulphite ions). Tests shall be carried out in accordance with the applicable approved international Standards.

D.7.3.5 Consistency

The quantity of water added to a batch of concrete shall be in accordance with ISO 22965 or EN 206, just sufficient to produce a concrete which, in the judgment of the Engineer, can be placed properly without segregation and which can be compacted by vibration to give the desired density and smoothness of surface. Also see Error! Reference source not found. .

Water content of aggregates shall be monitored at all times and adjustments made during batching to ensure that w/c ratio does not exceed the specified limits.

The consistency of the concrete shall be determined in accordance with EN 12350.

D.7.3.6 Mix Design

Samples of coarse and fine aggregates and cement proposed to be used in the works shall be tested. Tests shall be made at an authorised laboratory accepted by the Engineer.

From analysis and test of samples furnished, the laboratory shall design a concrete mix to meet the requirements for each class of concrete required for use in the works.

The laboratory shall prepare 2 test cylinders/cubes of each design mix from the samples furnished and test them after 7 and 28 days, respectively.

Three copies of the test results shall be submitted to the Engineer for approval.

D.7.3.7 Trial Mixes

As soon as the mix designs are approved by the Engineer, 3 batches of concrete for each of the represented classes of concrete shall be made on site under full scale production conditions using the same means and the same plant the Contractor proposes to use and approved by the Engineer.

The portions of cement, aggregates and water shall be carefully determined by weight in accordance to the approved mix design and sieve analyses shall be made in accordance with EN 12620 of fine and coarse aggregate used. In accordance

with EN 12350 three test cubes from each of the three batches shall be made by the Contractor in the presence of the Engineer from each trial mix.

The cylinders/cubes shall be made, cured, stored and tested as described in EN 12350.

If the average value of the compressive strength of the nine cylinders taken from any trial mix is less than the target mean strength or any individual cylinder test result falls below 85 % of the target mean strength, the Contractor shall redesign the mix and make a further trial mix.

D.7.3.8 Mixing of Concrete

All concrete prepared on site (smaller quantities of concrete) shall be mixed in accordance with EN 206 with batch mixers in accordance with approved international Standards.

The mixing of each batch shall continue not less than 1,5 minutes after all materials including water are in the mixer.

Hardened concrete or mortar shall not be permitted to accumulate on the inner surfaces of the mixer. Re-tempering will not be permitted.

D.7.3.9 Ready-Mixed Concrete

Ready mixed concrete shall be used with the written approval of the Engineer.

The Contractor shall certify to the Engineer that the ready-mixed concrete complies with the Specifications in all respects, and that the manufacturing and delivery resources of the proposed supplier as well as traffic conditions are adequate to ensure proper and timely completion of each concreting operation. The Contractor is obliged to submit to the Engineer all necessary attestations and certificates related to concrete production (condition of the plant, attestations and certificates for aggregate and cement, recipes, certificates for mixtures according to concrete strength classes, as well as other documentation related to the quality of produced concrete).

D.7.4 Reinforcement

D.7.4.1 Submissions and Approvals

In addition to other submission requirements in the Contract the following submissions are required:

- Manufacturer's test certificates for each delivery of reinforcing steel, showing the country of origin and tests;
- Manufacturer's data on accessories;
- All reinforcement drawings and bending schedules prepared by the Contractor.

Before concrete is placed against any formwork, the reinforcement shall be inspected by the Contractor and offered for inspection and approval by the Engineer.

In no case shall concreting be commenced prior to the inspection of the reinforcement by the Engineer and his written approval to proceed with concreting.

The approval procedure shall be supported by a 'pour - card' system (described in item D.12.2.2.2).

D.7.4.2 Steel Reinforcement

Steel reinforcement bars shall be hot rolled untreated bars conforming to the requirements of ISO 15698, ISO 6935-2019 and EN 10080. Only straight round bars -rebar type BSt 400/500 (minimum yield strength 400 N/mm²; tensile strength 500 N/mm²) and mesh BSt 500/600 shall be used. Steel wire reinforcement shall conform to the requirements of ISO 1569, ISO 10144 or EN 10080.

D.7.4.3 Accessories

The Contractor shall supply, use and install all necessary accessories such as reinforcing steel supports, hold-downs, spreaders, hangers, tie wire and all other incidentals necessary to complete an acceptable installation of all concrete reinforcement.

All accessories shall be of steel with the exception of spacers to maintain reinforcement distance and concrete cover.

If not otherwise directed by the Engineer, the concrete spacers shall be in the form of a truncated cone or pyramid and shall be used with the larger face towards reinforcing steel.

D.7.4.4 Cutting and Bending of Reinforcement

Bars shall be cut and bent in accordance with the provisions of ISO 22965, ISO 15835 and EN 206.

All bending shall be done cold with an approved bending machine.

Cut and bent bars shall be bundled and labelled for identification until they are incorporated into the work.

Re-bending or straightening of bars shall not be permitted.

D.7.4.5 Storage of Bars and Mesh

The Contractor shall stack separately and label the various type of reinforcement for identification.

Steel reinforcement shall be kept clean and free from pitting.

Loose rust, mill scale, oil, grease, earth paint or any other material impairing the bond between the concrete and the reinforcement have to be removed thoroughly before fixing.

Reinforcing steel shall be stored under cover on wooden supports, elevated from the ground surface.

D.7.4.6 Fixing of Reinforcement

All reinforcement shall be securely and accurately fixed in positions shown on the approved drawings using approved spacer blocks and dashboard mounts. The Contractor shall ensure that all reinforcement is maintained in position at all times, particular care being taken during placing of concrete.

The reinforcement in the meshes shall be fixed with the help of brackets / rods at a distance of no more than 90 cm from the centre. The reinforcement of the walls in two layers shall be maintained in position by means of 6 mm U or Z-shaped spacer at a distance of max 180 cm from the centre.

No part of the reinforcement shall be used to support formwork, access ways, working platforms or the placing of equipment.

Welding of reinforcement is subject to the permission of the Engineer.

D.7.4.7 Concrete Cover

Except as otherwise shown in approved drawings, reinforcement shall be installed with clearance coverage as follows:

- All surfaces in contact with water or placed against soil: 5.0 cm;
- Bottom of slabs over water and beams and columns not exposed to soil or water: 4.0 cm;
- Surfaces exposed to air and all interior surfaces in buildings: 3.0 cm.

D.7.4.8 Tolerances

Tolerances in placing reinforcement shall be:

- For members 60 cm or less in depth: ± 0.5 cm;
- For members more than 60 cm in depth: $+ 1$ cm / $- 0.5$ cm.

D.7.4.9 Approval by Engineer

In no case shall any reinforcing steel be covered by concrete until it has been inspected by the Engineer and his permission given in writing to proceed with the concreting.

D.7.5 Formwork and Concrete Finishes

D.7.5.1 Submissions

Before concrete is placed against any formwork, the formwork shall be inspected by the Contractor and offered for inspection and approval by the Engineer. In addition to submission requirements in these Technical Specifications the Contractor shall submit following documents:

- Design and shop drawings for formwork
- Layout of panels

In no case shall concreting be commenced prior to the inspection of the formwork by the Engineer and his written approval to proceed with concreting.

D.7.5.2 Requirements

Formwork shall be constructed of timber, sheet metal or other approved material, but meeting the surface finishing requirements.

The Contractor shall furnish all struts, braces and ties to withstand the placing and vibrating of concrete.

Except when otherwise expressly approved by the Engineer, all material brought on the Site as forms, struts or braces shall be new material.

The class of concrete finish is specified in Clause D.7.5.6. For each class of finish the Contractor shall present sample panels to the satisfaction of the Engineer. Sample panels shall not be less than 2 m² in area.

D.7.5.3 Form Ties

D.7.5.3.1 General provision

The maximum diameter of removable cones for rod ties, or of other removable form tie fasteners having a circular cross section, shall not exceed 40 mm and all such fasteners shall be such as to leave holes of regular shape for reaming.

Holes left by the removal of fasteners from the end of snap-ties or form ties shall be reamed with suitable toothed reamers so as to leave the surfaces of the holes clean and rough before being filled with a chemical mortar such as Sikadur 31 from Sika or equivalent approved product.

Wire ties for holding forms will not be permitted. No form-tying device or part thereof, other than metal, shall be left embedded in the concrete; nor shall any tie be removed in such manner as to leave a hole extending through the interior of the concrete member.

The use of snap-ties, which cause spalling of the concrete upon form stripping or tie removal, will not be permitted.

If steel panel forms are used, rubber grommets shall be provided where the ties pass through the form in order to prevent loss of cement paste.

Where metal rods extending through the concrete are used to support or to strengthen forms, the rods shall remain embedded and shall terminate not less than 50 mm back from the surface in the case of reinforced concrete and 150 mm in the case of un-reinforced concrete.

D.7.5.3.2 Watertight Ties

For concrete structures that shall be watertight, watertight ties shall be used (WÜRTH or H-BAU pentaflex opti or approved equivalent). These ties shall not require mortar sealing after removal of the formworks.

D.7.5.4 Number of Forms

A sufficient number of forms of each kind shall be provided to permit the required rate of progress to be maintained in accordance with the Contract and the approved Programme.

The design of concrete forms, false work and shoring shall comply with applicable standards.

D.7.5.5 Design of Formwork

All formworks must be adequate, safe and compliant with the Specifications and applicable standards:

- All forms shall be true in every respect to the required shape and size, shall conform to the established alignment and grade and shall be of sufficient strength and rigidity to maintain their position and shape under the loads and operations incident to placing and vibrating the concrete.
- Concrete construction joints will not be permitted at locations other than those shown on approved shop drawings. When a second lift is placed on hardened concrete, special precautions shall be taken in the location and tightening of ties at the top of the old lift and the bottom of the new to prevent any unsatisfactory effect whatsoever on the concrete.
- All exposed arises and exterior corners shall be chamfered (20 x 20 mm), unless specifically shown otherwise in the Contractor's approved shop drawings or directed by the Engineer.
- All vertical surfaces of concrete members shall be formed, unless placement of the concrete against the ground is called for and explicitly authorised by the Engineer. Permission for placing concrete against trimmed ground in lieu of forms will be granted only for members of limited height and where the properties of the ground allow for it.
- Top formwork shall be used on any inclined concrete surface steeper than 15° to the horizontal.

D.7.5.6 Formed Surfaces

Finishing to formed surfaces shall be fair finish according to CESSM 4 and defined as follows. Finish for surfaces which are exposed to view but where the highest standard of finish is not required. Forms shall be faced with wrought boards with square edges arranged in a uniform pattern or, alternatively, with plywood or metal panels, which are free from defects, disturbing the general appearance.

Remark: the specifications of this section also apply to surfaces that are not resulting from the use of formworks.

D.7.5.7 Erection of Formwork

All formwork shall be constructed, firmly supported, adequately strutted, braced and tied to withstand the placing and vibrating of concrete. Formwork shall not be tied to or supported by reinforcement.

Faces of formwork in contact with concrete shall be free from adhering matter, projecting nails and the like, split or other defects, and shall be clean and free from stagnant water, dirt, shavings, chippings or other foreign matter. Joints

shall be sufficiently water tight to prevent the escape of mortar or the formation of fins or other blemishes on the face of the concrete.

Formwork in contact with concrete shall be treated with suitable non-staining mould oil prior to reinforcement and concrete placement to prevent adherence of the concrete. Care shall be taken to prevent the oil from coming into contact with the reinforcement or with concrete at construction joints. Surface retarding agents shall not be used unless approved by the Engineer.

Where ties are built into the concrete for the purpose of supporting the formwork, the whole or part of any such support shall be capable of removal in such a way that no part remains embedded nearer than 5,0 cm from the surface. Holes left after the removal of such supports shall be neatly filled according to specification under D.7.5.3.

D.7.5.8 Tolerances

The permissible tolerances in the finished faces of shuttered concrete shall, if not otherwise directed, shall not exceed the following values:

Type of concrete works:	Buried concrete	Exposed concrete
Deviation from alignment	50 mm	10 mm
Deviation from grades	10 mm	10 mm
Deviation from dimensions	+10 / -5 mm	+10 / -5 mm

Deviation from alignment 50 mm 10 mm Deviation from grades 10 mm 10 mm Deviation from dimensions +10 / -5 mm +10 / -5 mm

D.7.5.9 Removal of Formwork

Formwork shall be designed as to permit easy removal without resorting to hammering or levering against the surface.

The period of time elapsing between the placing of the concrete and the striking of the formwork shall be as approved by the Engineer and shall be in any case not less than the period stated in EN 206. If not otherwise directed, the striking times for formwork shall be as follows:

- Side formwork for beams, walls, columns: 3 days
- Formwork for floor slabs: 8 days
- Formwork for beams, frames and long span slabs: 20 days

D.7.5.10 Dry Pack Mortar

D.7.5.10.1 Dry-Pack Mortar for Concrete Structures not in Contact with Water or Sludge

Dry-pack mortar for filling holes and repairing surface blemishes shall be from one part by weight of cement and three parts fine aggregate passing a 1 mm sieve and an expanding agent approved by the Engineer. Additives to improve workability may be added to the approval of the Engineer. The colour of the mortar shall match that of the surrounding concrete. The mortar shall be mixed with only sufficient water to make the materials stick together when being moulded in the hands.

The dry-pack material shall be placed and packed in layers having a thickness not greater than 15 mm. The compaction shall be carried out by use of hardwood stick and hammer and shall extend over the full area of the layer, particular care being taken to compact the dry-pack against the sides of the hole. After compaction the surface of each layer shall be scratched before further loose material is added. Holes shall not be over filled and the surface shall be finished by laying a hardwood block against the dry-pack fill and striking the block several times. Steel finishing tools shall not be used and water shall not be added to facilitate finishing.

D.7.5.10.2 Dry-Pack Mortar for Concrete Structures in Contact with Water or Sludge

Special dry-pack mortar for filling holes and repairing surface blemishes for concrete faces designed for contact with water or sludge shall be mixed of aggregates and cement as prescribed by the manufacturer. The colour of the mortar shall match that of the surrounding concrete. Placing shall be in accordance with the manufacturer's instruction.

Special dry-pack mortar shall have the following characteristics and shall be approved by the Engineer before being applied:

- Applicable under water;
- Persistent to wastewater or sludge or their ingredients harming concrete;
- Good workability;
- Good adhesion to the concrete surface;
- Low invariance and deviation in dimensions;
- Modulus of elasticity and heat expansion coefficient similar to concrete, and
- Compression, tensile, and bending tensile strength equal or higher than of the concrete to be applied.

Epoxy resin based mortars shall be used as bonding agent.

The Contractor shall provide material catalogues and method of application to the Engineer for his approval.

D.7.5.11 Remedial Treatment of Concrete Surfaces

D.7.5.11.1 General

Any remedial treatment to concrete surfaces shall be agreed with the Engineer following inspection immediately after the stripping of formwork and shall be carried out without delay.

Any minor surface blemishes as air or rock pockets, gravel streaks, sand streaking, dusting, surface scaling etc. shall be repaired to the satisfaction of the Engineer immediately after completion of curing. Subject to the Engineer's approval, remedial measures may include, but shall not be limited to, the following:

1. Holes left for formwork ties supports shall be thoroughly cleaned out to remove all loose material and the sides shall be roughened, if necessary, to ensure a satisfactory bond. They shall then be filled with appropriate dry-pack special mortar to be approved by the Engineer;
2. Air or rock pockets, Fins, pinhole bubbles, surface discoloration and minor defects may be repaired rubbed down with sacking and cement immediately the formwork is removed. with special repair mortar;
3. Abrupt and gradual irregularities like gravel or sand streaks may be rubbed down with carborundum and water after the concrete has been fully cured. Loose and/or sticking out aggregates shall be broken out, the defect places shall be repaired with special repair mortar;
4. Small defects and minor honeycombing shall be chipped out perpendicular to the face of the concrete to a depth of at least 25 mm and filled with special repair dry-pack mortar as specified in Sub-clause D.7.5.10;
5. Fissures shall be repaired according to Sub-clause D.7.5.12.

D.7.5.11.2 Repair Workmanship

The repair mortar shall be pre-shrunk by mixing it to a plastic consistency as far in advance of its use as possible. Trial mixes shall be made and aged to determine the longest period the mortar's use can be delayed while retaining sufficient plasticity to permit good workmanship.

Immediately prior to the application of the mortar, the damp surface of the area to be repaired shall be scrubbed thoroughly with a small quantity of neat cement ground, using a wire brush. Remaining loose sand particles shall be swept away immediately before application of the mortar.

In applying the mortar, it shall be compacted into the space to be filled, care being taken to eliminate air pockets and to secure bond at the edges. The surfaces shall be shaped and finished to correspond with adjacent surfaces of the pipe.

The newly repaired surfaces shall be kept damp for 24 hours after the repair is completed. A membrane coating of an approved white-pigmented sealing compound shall then be applied.

Epoxy resin as bonding agent shall be used as a in the manner prescribed by the manufacturer. The prepared area shall be primed with the epoxy resin compound, care being taken to insure intimate contact with the base material. Mortar shall be applied before the epoxy resin compound sets.

D.7.5.12 Concrete Injection

To repair cracks in concrete and if in the Contractor's opinion normal concrete repair methods as described above are deemed not to succeed, upon the Engineer's approval epoxy injection resin may be applied in order to effectively seal the crack to protect the reinforcement and to monolithically weld the structure together.

Before any injection application the cracks to be injected shall be to examined carefully to find the best injection method and material.

Injection material shall have the following characteristics:

- Low viscosity;
- High modulus;
- High penetration ability;
- High tensile and bond strength and durability;
- Non-shrinkable;
- Creating permanent, high-strength bonds between concrete surfaces when fully cured;
- Allowing for the normal transfer of loads designed into the original structure;
- Creating an impervious seal to air, water, chemicals;
- Good workability.

D.7.5.12.1 Equipment

For the equipment used to inject the resin, the Contractor shall meet the recommendations of the approved resin injection material manufacturer and the following requirements:

1. Equipment shall have the capacity to automatically proportion the material components within the mix ratio tolerances set by the resin materials manufacturer.
2. Equipment shall have the capacity to automatically mix the resin component materials within the pump and injection apparatus. The Engineer will not allow batch mixing.
3. Equipment shall have the capacity to inject the resin under controlled variable pressures up to 1.4 MPa, with a pressure gauge mounted at or near the nozzle to indicate the actual working pressure.

D.7.5.12.2 Injection Personnel Qualifications

Only personnel trained in performing injection work similar to that works required for the project shall carry out the resin injection of cracks in concrete. The Contractor shall provide an on-site supervisor for the resin injection work who

is sufficiently qualified certified by the manufacturer of the resin injection material as having the necessary competence to accomplish the epoxy injection work in a satisfactory and safe manner in compliance with these Specifications.

D.7.5.12.3 Crack Surface Preparation and Cleaning Requirements

The area surrounding the cracks shall be cleaned of all deteriorated concrete, efflorescence and other contaminants detrimental to the adhesion of the surface sealing resin compound. Clean the interiors of the cracks with air under sufficient pressure to remove loose materials entrapped within the crack including efflorescence.

D.7.5.12.4 Sealing Cracks for Epoxy Injection

After cleaning, injection port holes shall be drilled using a swivel drill chuck and hollow drill bits, including a vacuum attachment which will remove dust and debris generated during drilling. The spacing of the injection port holes shall be determined by the size of the crack and the depth of the crack in the concrete substrate. The actual spacing of injection ports shall be determined by field trials. The holes shall be drilled to the necessary depth, exercising care in aligning the hole along the plane of the crack so that the hole follows the crack for the full depth. Injection ports shall be inserted in the drilled holes, allowing for a small reservoir below the injection port.

After cleaning the cracks and drilling the injection port holes, the crack surface and the injection ports shall be sealed with approved suitable epoxy.

D.7.5.12.5 Epoxy Injection

The resin shall be injected in accordance with the approved resin manufacturer's instructions and chosen equipment. The actual injection procedures and pressures shall be determined in field trials, based on crack widths and depth into the substrate and sufficiency of the results.

The injection pressure shall be limited in order to avoid additional stressing of the crack, hydraulic lifting, rupturing of the cracked substrate, or further elongation of the crack.

Injection on very cold or hot concrete substrate or injection during cold or extremely hot weather shall be avoided.

When injecting resin against a head of water the cracks shall be sealed special high-mod epoxy gel adhesive to prevent water blowouts while injecting.

D.7.5.12.6 Cleaning after Epoxy Injection

The concrete surface areas shall be cleaned of excess epoxy materials and injection ports after completing the epoxy injection work. Cleaning shall be accomplished in a manner which will not damage the concrete by scraping, light sand blasting, grinding, use of solvents, or any other appropriate method approved by the Engineer. Excess materials shall be cleaned so that no epoxy material or injection ports extend beyond the plane surface of the concrete.

D.7.5.12.7 Acceptance

Failed injection work shall be corrected as necessary to the Engineer's satisfaction. Additional injection ports shall be installed as required to achieve satisfactory reinjection of epoxy resin.

After the epoxy injection work is completed and accepted, the core holes shall be filled with an epoxy mortar consisting of one part by volume epoxy injection resin and four parts by volume clean, dry sand.

D.7.6 Joints

D.7.6.1 Construction Joints of Watertight Concrete

D.7.6.1.1 Definition:

A construction joint is defined as a joint in the concrete introduced for the convenience of execution and at which special measures have to be taken to achieve subsequent continuity without provision for further relative movement.

Any and all construction joints shall be fitted out with central waterstop, and with sealant fillet in a groove if required elsewhere (H-BAU PENTAFLEX KB or approved equivalent).

D.7.6.1.2 Material of bonding Agent

The Contractor shall submit specifications for approval to the Engineer. Primer and bonding agent shall be from the same family of products offered by the same manufacturer.

D.7.6.1.3 Material of Sealant for Grooves

Prior to ordering the sealant material, the Contractor shall submit to the Engineer for approval sufficient data to demonstrate general compliance with the specification requirements. Primer and sealant shall be from the same family of products offered by the same manufacturer.

The sealant shall be two-pack polyurethane polymer specially designed for bonding to concrete continuously submerged in water and shall meet the following requirements:

Work life 45-90 mins. Time to reach "All hardness" (at 25°C, 200 gr quantity): 20 hours max.

- Ultimate hardness: 20 - 40 shore "A".
- Tensile strength: 16 kg/cm² min.
- Tear resistance: 120 kg/cm of thickness.

Alternatively a two-part polysulphide, gun grade, compliant with BS 4254 or similar may be used as a sealant subject to the Engineer's approval.

Certified test reports from the sealant manufacturer on the actual batch of material being supplied indicating compliance with the above requirements shall be furnished to the Engineer before the sealant is used on the works.

The primer and sealant shall be placed strictly in accordance with the recommendations of the manufacturer, taking special care to properly mix the sealant prior to application. Before any sealant is placed, the persons carrying out the work shall be carefully instructed as to the proper method of application.

All sealant shall cure at least 7 days before the structure is filled with water.

D.7.6.1.4 Material for PVC or Polymer central Waterstops

Central waterstops shall have 10 mm thick webs and be extruded from an elastomeric Polyvinylchloride compound containing the necessary plasticisers, resins, stabilisers and other materials necessary to meet the requirements of these Specifications.

The Contractor shall furnish to the Engineer current test reports and a written certification that the material to be supplied meets the following physical requirements:

Physical property, sheet material

- Tensile strength min [kg/cm²] 120
- Ultimate elongation min [%] 350

- Stiffness in flexure min [kg/cm²] 28

Accelerated extraction

- Tensile strength min [kg/cm²] 105
- Ultimate Elongation min [%] 300

Finished waterstop:

- Tensile strength min [kg/cm²] 100
- Ultimate elongation min [%] 280

H-Bau Pentflex KB (galvanized iron water stop sheet with resistant coating, 30 mm installation depth, up to 50 m water pressure) or approved equivalent with ETA certificate shall be used.

Prior to use of the waterstop material in the field, a cross section sample of a fabricated waterstop of each size or shape to be used shall be submitted to the Engineer for approval.

D.7.6.1.5 Field Splices of central Waterstops

Field splices and joints shall be made in accordance with the waterstop manufacturer's instructions using a thermostatically controlled heating iron. These samples shall be fabricated so that the material and workmanship represent in all respect the fittings to be furnished under this contract. When tested, they shall have a tensile strength across the joints equal to at least 42 kg/cm².

Horizontal waterstops shall be held in place with continuous supports to which the top edge of the waterstop shall be tacked.

Vertical waterstops shall be held in place with light wire ties at 45 cm centres, which shall be passed through the edge of the waterstop and tied to the two curtains of reinforcing steel.

D.7.6.1.6 Execution

Concrete placed to form the face of a construction joint shall have all laitance removed and the large aggregate exposed prior to the placing of fresh concrete.

The laitance shall wherever practicable be removed when the concrete has set but not hardened by spraying the concrete surface with water under pressure or brushing with a wire brush sufficient to remove the outer layer of cement mixture and expose the large aggregate without being disturbed.

Where the laitance cannot be removed due to hardening of the concrete, the whole of the concrete surface forming the joint shall be treated by high pressure water jet, sand blasting, use of a needle gun or a scaling hammer to remove the surface laitance.

When placing concrete around waterstops, concrete shall be worked under the waterstops by hand so as to avoid the formation of air and coarse aggregate pockets.

Where grooves are to be provided, the profiles used for forming the grooves shall be left in the grooves until just before the grooves are cleaned, primed and filled with joint sealant. After removing the form from the grooves, all laitance and fins shall be removed and the grooves shall be sandblasted.

The grooves shall be allowed to become thoroughly dry, after which they shall be blown out, immediately thereafter, they shall be primed and filled with the construction joint sealant.

D.7.6.2 Expansion and Contraction Joints, General

D.7.6.2.1 Definition

An expansion or contraction joint serves to absorb the relative movements of adjacent structures and is described on the Contractor's approved shop drawings. Any expansion or contraction joint shall be fitted out with a central waterstop, a joint filler and sealant finish that can follow the relative movement.

Such joints for expansion and contraction shall be constructed in accordance with the details and to the dimensions shown on the approved drawings or where otherwise ordered by the Engineer and shall be formed of the elements specified.

The Contractor shall pay particular attention to the effects of climatic extremes about the works on any material which he may desire to use in any movement joints and shall submit for approval by the Engineer his proposals for the proper storage handling and use of the said materials having due regard to any recommendations in this connection made by manufacturers.

D.7.6.2.2 Material of Bonding Agent

Same as under D.7.6.1.2.

D.7.6.2.3 Material of Waterstops

Central Waterstops shall be appropriate material (rubber strips / seals), and conform to the requirements specified before and elsewhere. All waterstops in one structure shall be of the same material.

Waterstops shall be supplied by the longest practical units from the supplier's works and shall be continuous throughout the structure below highest water level. Intersections and joints shall be factory made where possible.

Waterstops shall be carefully maintained in the position and supported on accurately profiled stop boards to create rigid conditions.

D.7.6.2.4 Material of Joint Filler

Joint filler shall be either cork / bitumen joint filler or cellular joint filler. Cork / bitumen joint filler shall be waterproof and rootproof and shall not extrude as a result of compression. Cork joint filler shall compress to less than 50 % of its original thickness with immediate recovery to 80 % or more of its original thickness.

Cellular joint filler shall be used only for joints of low horizontal loading and shall be a pre-formed low compression joint filler made from foam rubber. Cellular joint filler shall recover to its original thickness after each loading and unloading.

D.7.6.2.5 Execution

Preparation of concrete surfaces shall be applicable as under D.7.6.1.6.

The joint filler shall be fixed to the required dimensions of the joint cross section and shall provide a firm base for the joint sealer. Where the depth of joint between the concrete surface and the water stop does not exceed 500 mm filler shall be placed in single depth sections.

Sealing of expansion joints shall be carried out only when adjacent concrete surfaces are perfectly dry and as long after the concrete has been set as possible. Immediately before the application of the joint sealer the groove protection batten shall be removed in such lengths as represent a single day's work for sealing the joints.

The joint grooves shall be cleaned, adequately primed and filled with approved sealer strictly in accordance with the manufacturer's instructions and on joints of 25 mm and larger with a shape factor of 2:1 (width to depth).

On permanently exposed areas of structures joint sealing is to be carried out with the aid of masking tape to form neatly defined surface limits to the sealer.

D.7.6.3 Sliding Planes

Sliding planes on the concrete and joint blinding layers shall consist of a bitumen sand mixture 1 to 4 by volume spread evenly 3 mm thick over the carpet coat or of building paper either of which shall be applied immediately before the structural floor is concreted and shall be at all times suitably protected. Where building paper is used the concrete formation carpet shall be finished with a steel trowel to give a smooth surface.

Sliding joints shall consist of two layers of purpose made preformed plastic membrane which when in contact shall give a coefficient of friction of not more than 0,2 when subjected to a load of 270 kg/m². Where formed in concrete structures, the lower joint bedding surface shall be steel float finished to a smooth true surface.

D.7.7 Concreting

D.7.7.1 Preparing for Concreting

For the preparation of concreting, the following shall apply:

- No concrete shall be placed until all provisions and related aspects (such as formwork, installation of reinforcement and parts to be embedded and preparation of surfaces involved in the placing...etc.) have been approved by the Engineer;
- Each surface shall be free from mud and debris and be thoroughly wetted by sprinkling prior to the placing of any concrete;
- For watertight structure all slabs, beams and walls shall be concreted in one batch.

Before any lift of concrete is placed, the Contractor shall carry out an inspection to ensure that all preparations are complete, including the provisions of the necessary equipment and personnel and shall ensure that sufficient materials are available to complete the works proposed.

D.7.7.2 Transporting and Placing

Concrete shall be transported from the mixer to its place in the works as rapidly as possible by approved methods which will prevent segregation or drying out and ensure concrete of the required workability at the time of placing:

- Concrete shall not be placed when unsuitable wind and temperature conditions prevent proper placement and curing as determined by the Engineer;
- Concrete shall be placed by hoppers and chutes and, if necessary, by vertical ducts;
- The free fall of concrete after chutes and ducts shall in no case exceed 1,5 m;
- Concrete shall not be dropped through any reinforcement or into any deep form in order to avoid segregation;
- Concrete shall be placed and compacted before the initial set has occurred and, in any event, not later than 45 minutes from the time of mixing.

Concrete shall be delivered to the construction site with accompanying documentation (delivery note with detailed quantities of each represented fraction of stone aggregate, quantity of cement and water, name and quantity of additives, etc.). The concrete shall be placed in the presence of the Engineer, unless agreed otherwise. The Contractor shall notify the Engineer in writing 24 hours prior to the placing of any concrete.

The order of placing in all parts of the work shall be subject to the approval of the Engineer.

In order to minimise the shrinkage, the concrete shall be placed in units as bounded by construction joints. The placing of the units shall be done in such a way that each unit shall have cured for at least 7 days before the contiguous units are placed, with the exception of walls which shall be placed not before the wall footings or adjacent wall panels have cured for at least 14 days.

Whenever a run of concrete is stopped or completed, the surface of the concrete shall be levelled with a trowel and all laitance shall be removed.

D.7.7.3 Compaction

As concrete is placed in forms or in excavations, it shall be thoroughly settled and compacted, throughout the entire depth of the layer which is being consolidated, into a dense, homogenous mass, filling the form completely, thoroughly embedding the reinforcement, eliminating air and aggregate pockets and bringing only a small amount of excess water to the surface of concrete during placing.

For compaction the Contractor shall use power driven vibrators supplemented by hand spading and tamping, except as otherwise approved by the Engineer.

A sufficient number (including stand-by) of appropriate sizes vibrators shall be available on Site at all times.

D.7.7.4 Attendance of Steel Fixer and Carpenter

When concreting reinforced concrete, a competent steel fixer and carpenter shall be in attendance on each concreting gang to ensure that the reinforcement, formwork, spacers and embedding fittings are kept in position as works proceed.

D.7.7.5 Concreting in Hot Weather

The temperature of concrete as placed shall not exceed 30°C in order to prevent rapid drying of the newly placed concrete. To achieve this, the Contractor shall provide sunshades over aggregate stockpiles, cement silos and mixing water tanks and preferably place concrete during the night hours.

With the approval of the Engineer, also the following procedures may be applied:

- Cooling of mixing water by chipped ice;
- Sprinkling of stock piles with water;
- Shade or wet the outside of the formwork.

The fresh concrete shall be shaded and cured as soon as the surface of fresh concrete is sufficiently hard.

D.7.7.6 Concreting in Cold Weather

Cold weather is defined as the situation existing at the Works, where either or both of the following conditions exist:

- The air temperature at the time considered is below 2°C;
- The mean daily air temperature over three or more successive days has dropped below 5°C.

Under no circumstances may concrete be placed in contact with frozen ground or formwork, or in contact with ice, snow or frost on the ground or on formwork or reinforcement. Concrete shall not be made with frozen materials.

Concreting may proceed in cold weather provided that special precautions approved by the Engineer are taken to ensure that the surface temperature of the concrete at the time of placing is not less than 5°C for a succeeding period of at least:

- 4 days when the cement used in the concrete is ordinary Portland cement;
- 2 days when the cement used in the concrete is rapid hardening Portland cement.

Such precautions may include the following:

- Warming the aggregates and heating the water, provided that the temperature of either does not exceed 60° C. Water and aggregates shall be mixed for a period sufficiently long for them to acquire a uniform temperature before cement is added;
- Completely surrounding the freshly placed concrete with a cover and heating the enclosed air, which shall be kept moist. Draughts of hot or dry air shall not be directed at surfaces;
- Insulating the formwork and finished concrete surfaces;
- Providing screens to protect the concrete from air currents.

The Contractor shall provide the Engineer with details of the precautions he proposes to take to protect the concrete from the effects of low temperatures and with details of the methods he proposes to use assess the correct timing at which such protection may be removed.

No concreting shall be done in cold weather prior to the approval the Engineer for the proposed measures.

D.7.7.7 Concreting in unfavourable Weather

Concreting shall not be permitted during heavy rain or snowfall, or when the air temperature falls below 2 °C, or when the concrete temperature rises above 30 °C. When the air temperature exceeds 25 °C, concreting shall only be permitted after special precautions, approved by the Engineer, have been taken to prevent early setting of the concrete, such as lowering the temperature of the water to be used in the mix or by means of a cooling-system, keeping the aggregates and shutters continuously sprayed with water and erection of temporary sun shades over the working area. During concreting operations the temperature of the placed concrete shall be recorded.

D.7.7.8 Curing of Concrete

All concrete shall be cured by protecting the surface from the effects of sun, drying winds, rain, running water or mechanical damage for a continuous period of at least seven days by:

- Keeping wooden formwork wet until it is removed;
- Covering the concrete surface with burlap mats and keeping them wet;
- Covering the surface with moist earth (not before 4 hours and not longer than 24 hours after concreting);
- Spraying the surface with water or a liquid curing compound.

D.7.7.9 Care and Repair of Concrete

The Contractor shall protect all concrete against injury or damage from excess heat, lack of moisture, overstress or any other cause until final acceptance by the Engineer.

Any concrete found to be damaged, which may have been originally defective, which becomes defective prior to the final acceptance of the completed work or which does not conform to the Specification, shall be repaired or removed and replaced by the Contractor to the Engineer's satisfaction.

Repair of concrete must be made by a proper mortar which is designed for only repair purposes; e.g., SIKA Monotop 610 – 604 – 620 (or equivalent approved products).

Mortar for concrete repair works must be approved by the Engineer prior to the commencement of any repair works.

D.7.7.10 Finish of Concrete Surfaces

Workmanship in formwork and concreting shall be such that concrete does not require making good, i.e. surfaces are perfectly compacted, smooth and with no irregularities. Surfaces shall be free from fins, bulges, ridges, offsets, honeycombing or roughness of any kind.

Except if otherwise provided, unformed top surfaces of concrete shall be brought to a uniform surface and worked with suitable tools to a smooth wood-float finish. Excessive floating of surfaces while the concrete is plastic will not be permitted.

As soon as forms are removed, all exposed surfaces shall be carefully examined and any irregularities shall be immediately rubbed or ground in a satisfactory manner in order to secure a smooth and uniform surface.

Plastering or coating of surfaces shall not be permitted. No repairs shall be made until after inspection by the Engineer and then only in strict accordance with his instructions.

D.7.7.11 Prefabricated Concrete Members

Prefabricated concrete members shall be obtained from an approved manufacturer or prepared by special skilled employees upon Engineer's approval, and shall be true to dimension and shape, with true arises and with perfectly smooth exposed faces free from surface blemishes, air holes, crazing or other defects, whether developed before or after building- in.

The prefabricated concrete members shall comply in every respect with the provisions of the contract whether such units are manufactured on the site or obtained from approved manufacturers.

All cement, aggregate and other materials for precast concrete units with faces which are exposed whether internally or externally, shall be from the same sources throughout.

Exposed surfaces of the units shall be uniform in colour and in texture.

Formwork and unformed surfaces for prefabricated concrete members shall comply generally with the accuracy grade "C".

D.7.7.12 Pre-stressed Concrete

Pre-stressed concrete work whether prefabricated or cast in-situ shall be as detailed on the approved drawings and the Contractor shall submit to the Engineer for approval full details of his proposed method of carrying out all operations connected with pre-stressing including:

- Design of concrete mix; description of concrete casting and curing operations;
- Procedure for pre-stressing and method of checking and recording the pre-stressing wire extension and anchorage slip;
- Procedure for handling, hoisting and placing of any pre-cast units;
- Grouting of ducts.

All tendons, duct forming devices, anchorages and other components shall be kept free of mud, oil paint, retarders, loose rust or other foreign matter. They shall be placed with a tolerance of ± 3 mm in concrete dimensions of 300 mm or less or ± 6 mm in concrete dimensions over 300 mm.

The bearing surfaces between anchorages and concrete shall be normal to and concentric with the tendons and the line of action of the pre-stressing force.

D.7.7.13 Concrete for Benching

Concrete benching in chambers and works structures shall consist of concrete with adequate consistency and aggregate sizes. It shall be placed with low workability to the approximate shape required and, while still green, shall be finished with not less than 50 mm of concrete to a steel trowelled finish and to the contours indicated on the Contractor's

approved shop drawings. To prepare the final layer of the concrete benching, a sand of fraction 0-4 mm with the appliance of sulphate-resistant cement (CEM III), shall be used.

D.7.7.14 Pumping Concrete

Where pumping of concrete is permitted to be used, no relaxation of the requirements of this Specification will be permitted.

Particular attention shall be paid to the proper grading of aggregates to prevent bleeding and/or segregation during the pumping operations.

The inclusion of water-reducing additives or other materials such as fly ash, to improve the flow characteristics of the concrete will only be permitted upon Engineer's approval.

D.8. Road Works

D.8.1 General requirements

This section covers the technical requirements for the road works, as specified in the Contract including the construction or reinstatement of roads and pavements as directed by the Engineer.

All materials shall be new and shall comply with standard quality and dimension provisions. Non-standardised materials and building components shall be subject to the Engineer's approval and the Contractor shall, at the request of the Engineer, provide samples, details and name of manufacturer...etc. to the Engineer's satisfaction.

Mineral materials shall be weatherproof, of adequate hardness and of sufficient adhesion to bind. They shall not contain any swelling, weathering, loamy, clay or organic components in harmful quantities.

Bituminous mixes shall be blended so as to be suitable for the purpose of application. Special consideration shall be given to climatic conditions, volume and type of traffic.

D.8.1.1 General Road Layer Structure

D.8.1.1.1 Top or Wearing Course

Top courses shall fulfil the following requirements in generally: good evenness, good grip, good sealing against lower layers against precipitation, low void content, high resistance against deformation:

- Minimum layer thickness: 3 cm (for bituminous wearing course) respectively 14 cm for concrete wearing course;
- Material: bituminous concrete, hot mix asphalt, asphalt mastic, concrete;
- Grading: 0/5, 0/8, 0/11, 0/16 (for bituminous wearing course).

D.8.1.1.2 Binder Course

Binder courses shall fulfil the following requirements in generally: high resistance against deformation, good equalisation of unevenness of substratum, good shear acceptance:

- Minimum layer thickness of bituminous binders: 4 cm;
- Material: bituminous concrete with high void content;
- Grading for bituminous binders: 0/11, 0/16, 0/22.

D.8.1.1.3 Base courses

Base courses shall ensure a regular force distribution, be frost proof and fulfil the following requirements:

- Minimum layer thickness: 8 cm;
- Material in case of bituminous binders and top layers: bituminous base course, hydraulically bound base course;
- Material in case of concrete top layers: hydraulically bound base course;
- Grading: 0/22, 032.

D.8.1.1.4 Roads to be Reinstated

The roads and pedestrian access pavements to be reinstated may include the following types of surfacing:

- Asphalt concrete pavement on a macadam base;
- Asphalt concrete pavement on a cement stabilised gravel base;
- Double bituminous surface treatment on a cement stabilised base;
- Double bituminous surface treatment on a selected gravel base;
- Natural cobblestones;
- Gravel roads and foot paths;
- Tiled pavements.

For the precise details of materials to be used and thickness of construction, the Contractor shall refer to the Technical Requirements of the Local Road & Highway Authority and international standards.

D.8.2 Maintenance and Reinstatement of Existing Roads and Footpaths

The Contractor shall maintain existing roads and footpaths within the Site. He shall reinstate the pavements, curbs and other parts of the roads after execution of works to its original state.

Temporary reinstatement of public roads shall be carried out as soon as is practical after completion of the Permanent Works and before the Part of the road or pavement is re-opened for public use. Temporary reinstatement shall be maintained by making good any subsidence, shrinkage, defect, imperfection or fault a period as directed by the Engineer but at least 3 months prior to final reinstatement.

The Contractor shall remedy any settlement occurring after execution of works immediately upon notification by the Engineer.

Such remedy of pavement shall be done to the Engineer's satisfaction and may include the re -excavation of the top surface, base and sub-base, the backfilling of base and sub-base with graded aggregate and the reinstatement of the surface.

D.8.3 Sub Grade

Sub grade shall be graded and compacted to the levels, falls, cambers as required by approved international standard and shall be compacted so that the dry density of the upper 15 cm of the ground or fill is not less than 95 % Proctor of the maximum dry density determined by tests. Where the sub grade is the natural soil, compaction shall be carried out at or near to the natural moisture content of the ground.

Material not suitable to reach the required density shall be removed and replaced with material for granular sub base.

Surface of sub grade shall be kept free of standing water at all times and drains shall be provided so that it will drain quickly and effectively during rain.

Any irregularities or depressions that develop during compaction of the sub grade or any area which becomes muddy, broken-up or loosened due to weather conditions shall be corrected by loosening the surface of these places and adding, removing or replacing these materials and re- compacting so that the surface is smooth and uniform to the Engineer's satisfaction.

D.8.4 Pavement

D.8.4.1 Sub-base and Road Base

The sub base and road base shall be graded and compacted to the levels, falls, cambers and densities as required by approved international Standards and as shown on the Contractor's approved shop drawings.

The materials for sub-base and road base shall be laid in layers, each not exceeding 15 cm or being less than 10 cm. The total compacted thickness of sub-base and road base shall nowhere be less than the specified nominal thickness. If not otherwise directed by the Engineer, the sub-base and base in roads shall have each a thickness of 20 cm, in footpaths a thickness of 15 cm.

The sub-base and road base materials shall be deposited in such a manner that there is no segregation and the materials require the minimum of blading or spreading. Each layer of material shall be compacted immediately after spreading in accordance with international Standard. If any of the sub grade material is worked into the sub base material during spreading, profiling or compaction, all the sub base material in the affected area shall be removed, the sub-grade compacted again and fresh sub base material shall be placed to the Engineer's satisfaction.

On completion of compaction and before commencing the next operation, the surface of the granular sub base and road base shall comply with a surface tolerance of ± 1 cm.

D.8.4.2 Surfacing, General

Wherever possible, the operations of final trimming of the formation, compaction of the sub grade and placing and compaction of the granular sub-base and road base shall be carried out immediately one after another.

The Contractor shall take all necessary steps to prevent damage to the previously completed layer or layers by excessive wetting or drying out due to weather conditions or by traffic or any other cause. If the contractor considers it as advisable or if so instructed by the Engineer, the completed layers shall be sealed using bitumen road emulsions.

In any case, the completed surface of the road base shall be sealed with suitable emulsion (M.C. 70) at a rate of 1,5 to 2,0 kg/m² immediately when it has been completed and checked for compliance with the specified tolerances.

D.8.4.3 Flexible Pavement

Unless otherwise specified or instructed by the Engineer, materials for flexible pavement shall be asphaltic concrete and asphalt, in a quality corresponding to the approved international standards and applicable local regulations. The surface on which each course of coated bituminous material to be laid shall be free from standing water and any loose or deleterious material and shall be tested for accuracy.

Before laying commences in any area, a tack coat of bitumen road emulsion shall be applied to the whole area of the preceding course and any other surfaces with which the coat will be in contact.

The top of the base shall be sprayed with suitable emulsion (M.C. 70) at a rate of 2,0 kg/m²; the surface of the bituminous coat shall be treated with asphalt tack coat (RC-250) at a rate of 0,5 kg/m². The emulsion shall be allowed to break completely before the subsequent bituminous layer is laid on it.

Heaters used for bitumen shall conform to BS 1676 and the heated bitumen shall be applied by self-propelled pressure distributors with spray bars complying with BS 1707 or BS 3136. Where different grades of bitumen are used, heaters and distributors shall be thoroughly cleaned before the grade of bitumen is changed. Flushing from heaters and distributors shall be drained to disposal pits and not discharged into drains, ditches or watercourses. Any bitumen heated above the maximum specified temperature shall be removed from the Site and replaced by the Contractor. Hand spraying shall only be used if approved by the Engineer.

Where spraying is commenced or stopped, metal sheets or building paper shall be spread across the width of area to be sprayed to produce a clean sharp edge to the area. The sheets shall be cleaned daily and the building paper properly destroyed after use.

During spraying, all kerbs, headwalls and other road furniture shall be protected from bitumen splashing.

During the course of the work only essential construction equipment shall be allowed into the area and not allowed to stand on completed work. The road shall not be opened to general traffic until directed by the Engineer.

Coated macadam material shall be delivered to site in clean vehicles and shall be covered to minimise loss of heat in transit and against contamination by dust or other deleterious matter.

Binder for surface dressing shall only be applied upon completion of the priming and when any defect to the primed surfaces have been repaired. No binder shall be applied until primed surfaces have been approved by the Engineer.

Aggregate shall be spread, by mechanical chip spreaders, immediately following the spraying of the binder and no work are to commence until sufficient supplies of aggregate are at hand. Manual spreading of aggregate shall only be permitted when approved by the Engineer. After applications of aggregate, the surface shall be lightly broomed to give a uniform coverage with no areas having an excess or deficiency of aggregate. Within 20 minutes of application and brooming of the aggregate, the surface shall be rolled with a self-propelled pneumatic-tyred roller, weighing not less than five tons, until a smooth, well-compacted surface is obtained.

Upon completion, all loose aggregates shall be removed from the surface for proper disposal off the site.

Bitumen binder shall be straight run 80/100 penetration grade bitumen and the first seal coat shall consist of bitumen sprayed at the rate of 1.2 l/m² of surface area and 19 mm aggregate spread at the rate of 70 m²/m³ of aggregate. The second seal coat shall consist of bitumen sprayed at the rate of 1.2 l/m² of surface area and 12 mm aggregate spread at the rate of 100 m²/m³ of aggregate.

Aggregate grading shall be as follows:

Sieve (mm)	20	14	10	6.3	5	3	2	0.5
First seal	100	85 - 100	0 - 30	0 - 7	-	-	0 - 2	-
Second seal	-	100	85 - 100	0.30	0 - 10	-	0 - 2	

First seal 100 85 - 100 0 - 30 0 - 7 - - 0 - 2 - Second seal - 100 85 - 100 0.30 0 - 10 - 0 - 2

and should have the following aggregate requirements:

- Los-Angeles Abrasion (LAA): max. 35
- Aggregate Crushing Value (ACV) max. 26
- Sodium Sulphate Soundness (SSS) max. 12
- Flakiness Index (FI) max. 25

The rate of delivery to the site shall be regulated so as to enable the material to be laid with a minimum of delay and so that the paver can operate continuously.

The coated thickness of individual layers shall be not less than the minimum compacted thickness specified or as shown in drawings. If not otherwise directed, the bituminous base course shall have a thickness of 10 cm, the wearing course of 5,0 cm.

D.8.4.4 Rigid Pavement

Rigid paved areas shall be constructed in concrete in accordance with approved international Standards and with the relevant requirements of the Specification for Concrete Works.

Concrete shall be in accordance with ISO 22965 and EN 206 and it shall include an exposure class of at least XM1.

Concrete for rigid pavement shall be of class C 20/25. The use of additives shall be subject to the approval of the Engineer. Concrete courses shall be never less than 100 mm thick.

Transport and placing of the concrete shall be co-ordinated so that the concrete can be completely placed before setting.

Expansion joints shall be executed at the required intervals and shall enable expansion to the concrete slabs and be fixed. The expansion joints shall be 20 mm wide. The strength of the concrete and the properties of the concrete surface shall not be influenced by the execution of joints.

The concrete shall be protected against harmful influences until correct setting, i.e. against drying out, especially due to sun and wind, against washing out due to rain, against heat or quick cooling. The concrete surfaces shall be cured and kept moist for 7 days.

D.8.4.5 Kerbs

Kerbs shall comply with the following Standards:

- EN 1343 Kerbs of natural stone for external paving – Requirements and test methods;
- EN 1340 Concrete kerb units - Requirements and test methods.

Kerbs shall be laid true to line and level. Kerbs found to be more than 1 cm out of line or level at either end shall be lifted and re-laid.

The kerbs shall be laid on a layer of 3:1 sand / cement mortar, minimum 10 cm thick of strength class C 8/10, shall be placed, and the kerb shall be shaped with concrete to the required cross section. Kerbs shall be jointed with cement mortar, except for expansion joints, which shall be made with a joint filling compound, 10 mm thick.

D.8.4.6 Footpaths

Footpaths shall be surfaced with coated macadam, concrete, pre-cast concrete slabs or natural stones. The base for footpaths shall be formed from flexible surfacing, laid and compacted to a minimum thickness of 100 mm using a roller of at least 2 tons mass or other approved equipment allowing for equivalent compaction.

Where footpaths receive coated macadam surfaces, the construction shall be as follows:

- pre-cast concrete edging in accordance with the appropriate Standards as mentioned above shall be bedded and backed with in-situ concrete C 8/10;
- the base shall be constructed as specified above and shall then be sealed;
- the surfacing shall consist of a single course of coated macadam and be compacted to minimum thickness of 25 mm.

Pre-cast concrete slabs shall be bedded on a layer of sand, of thickness not less than 50 mm, and tamped into place.

Natural stones shall be sound, durable, hard and free from undesirable weathering and shall be of such properties that they will not disintegrate from the action of weather in handling and placing.

The density of stones shall be not less than 2,2 t/m³ (solid volume without voids).

The dimensions of stones shall range between 150 and 200 mm.

The stones will be rough hammered dressed so that they fit reasonably close together.

They shall be laid to a true and even surface on a layer of sand, approximately 100 mm thick and tamped into place.

Concrete footpaths shall be surfaced with concrete C 20/25, at least 10 cm thick with mortar topping, constructed on a prepared bed as specified above and in accordance to the Specification for Concrete Works.

D.8.4.7 Disposal of surplus Material

Unless otherwise directed by the Engineer, the Contractor shall make his own arrangements to dispose of all surplus backfill and unsuitable excavated material from any part of the Work.

The material shall be disposed off-site and shall become the property of the Contractor who will be entirely responsible for its removal from the Site and its ultimate disposal.

The Contractor shall clean the Site and the surrounding ground immediately and leave the construction sites clean and tidy to the satisfaction of the Engineer.

D.9. Drainage Works

D.9.1 Piped Systems

Specifications for sewers shall apply (see section General Technical Specifications Part C).

D.9.2 Open Channels

Open channels shall be constructed either as earth channels, in stone work or with pre-cast concrete elements in half-round or rectangular sections.

Open channels adjacent to buildings, basins or other structures and channels with longitudinal slope steeper than 1:100 shall be constructed with pre-cast concrete or stone work, depending on soil conditions. Channel sections, which are subject to scouring, shall be protected with stone pitching.

Structural design of pre-cast concrete channels shall be submitted to the Engineer for approval. All backfilling shall be with selected approved material. If the soil is unsuitable for laying of channels, the Contractor shall place a bedding layer of approved granular material or concrete C 8/10 under the channel.

All road crossings of channels shall be constructed such that vehicular traffic is not exposed to danger.

The Contractor shall provide for the installation of pipes and culverts or grating over the channel.

D.10. Fencing and Gates

D.10.1 General

Internal fencing shall be of the standard type and fencing around the perimeter of the site shall be of the security type. Security fences shall be anti-intruder type.

All items of material for fencing shall be standard products of specialized manufacturers. Posts and struts shall be either reinforced concrete or galvanized steel sections. Timber posts shall not be used. Steel posts shall be closed at the top with plastic or cast zinc alloy caps.

The distance between the posts shall be a maximum of 3,0 m. The posts are to be set in stable C 20/25 concrete foundations. This applies also to the required cross braces for the corner poles.

Intermediate straining posts are to be installed to max.20 m intervals and at changes in line or direction. They shall have two diagonal struts and shall be provided with 3 double ratchet winders for the strain line wires and one joint clamp to fix the struts to the post. Strut foundations shall be cast in concrete C 20/25 and in sufficient size.

All wire shall be galvanized wire with plastic coating. The length of the sides of the chain link mesh shall be 50 mm. Sufficient straining wires, winding ratchets, joining clamps and other fittings required shall be provided for all end, corner and gate posts.

The steel mesh shall be secured to the posts at 0.30 m intervals along the height of the posts and the chain link fence shall be supported by fixing to 3 wires strung from post to post.

All posts and struts shall be anchored in rigid concrete C 20/25 foundations of sufficient depth. In the vicinity of gates, structures and fence openings, adequate provisions to fix the fences shall be provided.

D.10.2 Standard Fencing

Standard fencing shall consist of a 1.0 m high mesh wire fencing with steep posts of circular tubing of high tensile steel as approved by the Engineer.

The posts shall be galvanized inside and outside and plastic coated and closed at the top with plastic or cast zinc alloy caps. End, intermediate, corner and straining posts shall be 1.5 m long, gate posts 1.5 m long.

Corner and end posts shall either be supported by struts as for intermediate straining posts or by a horizontal bracing. Sufficient straining wires, winding ratchets, joining clamps and other fittings required shall be provided for all end, corner and gate posts.

Three rows of straining wires are to be installed for 1.0 m high fences.

D.10.3 Security Fencing

Security fencing shall be constructed as described for standard fencing, but with posts provided with barbed wire holders inclined outwards along the top edge.

The total fence height shall be 2.5 m. Six rows of straining wires are to be installed. The post length shall be 3.0 m minimum. Posts shall be anchored in foundations of a width/length 40 x 40 cm and a depth of at least 40 cm, filled with concrete class C 20/25.

Three rows of galvanized and plastic coated 2 strand, 4 point barbed wire shall be fixed to the cranked top section of the post. Sufficient ratchet, winders and clamps are to be provided to assemble and to secure the barbed wire.

D.10.4 Gates

Access gates shall be made of:

- a steel frame consisting in rectangular or round hollow parts of sufficient strength, width and height or diameter not less than 5 cm, wall thickness not less than 3 mm. The frame shall be 2.0 m in height;
- filling rods placed vertically into the frame in a distance not less than 10 cm and consisting in rectangular or round hollow parts of sufficient strength, width and height or diameter not less than 3 cm, wall thickness not less than 2 mm.

The whole frame including filling rods shall be factory welded, hot-dip galvanised and 2-layer coated.

The tops of the gate frames shall be levelled with the tops of adjacent fencing (excluding barbed wire holders). All gates shall be surmounted with galvanized plastic coated barbed wire to match the fencing.

Man-gates shall be hinged single-entrance gates with a clearance of 1 m.

Car-gates shall be motor-driven mono-rail based sliding gates with a clearance of at least 6 m. Motor, gearbox and drive wheel / pinion shall conform to the requirements. Sliding gates shall be provided with roller support tracks.

The gate shall be equipped with an automatic emergency stop mechanism to avoid persons to be shut between gate end and limit stop. Furthermore an additional emergency stop push button shall be installed. The gate shall be lockable with a key control switch.

Motor control shall be as follows:

- Gate opens automatically for cars leaving the plant by means of an inductive loop placed below the road surface in an appropriate distance from the gate. Gates closes automatically controlled by free adjustable timer;
- Higher-ranking manual remote and key switch open-close control to be operated by the Security Staff;
- Higher-ranking emergency stop.

The Contractor shall submit to the Engineer's approval the detailed specifications of the gate system (gate, motor -drive, control).

Each man- gate shall be supplied with a padlock and three keys all to the Engineer's approval.

The gates shall be complete with all fittings such as drop bolts, back catches, locking bars, lock plates and locks including three keys per lock, etc.

D.10.5 Installation

Fences shall be installed in accordance with the fence manufacturer's drawings and written installation instruction and to the Engineer's satisfaction. Each line of fencing shall be erected so that it is plumb, taut, true to line and grade, and complete in all details. The outside face of the fabric shall be on the property line where the fence runs along the property boundary. Posts shall be suitably braced during concreting to ensure that they remain in the correct line and level during placing of concrete and the concrete shall be cured for 3 days before any further work is done at the post.

D.11. Landscaping

D.11.1 General

All areas of the Site not occupied by treatment units, buildings, roads or footpaths, etc. shall be evenly graded to a uniform surface and shall receive an extensive greening. The vegetation of these areas shall correspond to the vegetation presently encountered on and around the Site, be suitable for local conditions and require minimal maintenance.

Areas near buildings shall be covered with lawn, bushes and trees.

The Contractor shall prepare and submit to the Engineer's approval prior to the start of the landscaping works, a landscaping scheme shown in a plan at a scale of minimum 1:1000 and including the proposed species of grass, trees and shrubs.

D.11.2 Topsoiling

So far as practicable, top soil shall be obtained from material emanating from excavations and separately stored in temporary spoil tips as specified and directed by the Engineer. If deemed necessary by the Engineer, he may instruct the Contractor to provide extra material from an approved source off the site for this purpose.

Topsoil shall be evenly spread and trimmed over embankments and filled excavation to the slopes and levels as shown on the Contractor's approved shop drawings. The depth after spreading and trimming shall be 250 mm measured perpendicular to the surface. All clods and lumps shall be broken up and any rubbish, large stones, roots and weeds shall be removed to the Engineer's satisfaction.

Where the upper layer of natural soil is poor in organic matter, it shall be improved to a minimum depth of 25 cm by adding either clay or sand or silt to create a loamy soil texture consisting of 40 % Sand (size > 0.05 mm), 30 % silt (size 0.05 - 0.002 mm) and 30 % clay (size < 0.002 mm).

A shallow ripping will be required before adding clay or sand or silt which should be under mixed properly by using a disk harrow. If it should be necessary for topographical reasons, levelling may be carried out before mixing clay, sand or silt.

D.11.3 Grassing

Where the topsoil shall be sown with grass seed, the top 75 mm of the previously laid topsoil shall be brought to a fine tilt suitable for seeding, and sowing shall be carried out as soon as practicable after completion of topsoiling having due regard to the season and the weather conditions. If ordered by the Engineer, subsoil lime and fertilizer shall be applied in accordance with his directions.

After the seed has been sown uniformly, they shall be raked and lightly rolled into the surface. The young grass shall be kept free from weeds and any bare patches shall be re-seeded until an even close turf is established. The grass shall be watered, mown and rolled as required and maintained in good condition until the expiry of the period of maintenance.

The Contractor shall replace any and all damaged areas where the grass has dried up or has not adhered to the slope surface, which contains undesirable plants or which has an irregular or unattractive appearance in the Engineer's opinion.

D.11.4 Shrubs and Trees

Trees and shrubs shall not be planted at locations where roots may destroy or infiltrate buried pipes or cables or where lapsed leaves may fall or blown into open tanks. Number, species and location of trees and shrubs shall be approved by the Engineer before planting.

Trees and shrubs shall be of the species proposed by the Contractor, approved by the Engineer, of the best quality and free from disease and suitable for the climatic conditions on site. They shall be young stock or in the case of shrubs may be established seedlings or cuttings. All must be sufficiently mature to survive transplanting from the supply nursery.

The root systems of all plants shall be maintained intact in the soil in which they have been grown and may be supplied in containers.

All trees and shrubs and other plants shall be supplied by a nursery approved by the Engineer.

Prior to planting, holes for trees and shrubs shall be prepared and filled twice with water. Plants shall be watered in their containers so that the soil and the roots are kept in a moist condition. Plants shall then be removed from their containers and their root ball complete with soil set in place and the holes backfilled and the plants firmly trodden in.

Soil shall not be allowed to rise above the original container level and the ground level around the trunk or stem shall be set below adjacent ground to retain irrigation water.

All species of trees and shrubs where required shall be provided with supports during planting. These shall take the form of timber stakes of adequate strength driven into the ground adjacent to the trunk or stem without damage to roots. Wide hessian strips shall be used to tie the plant securely but not tightly to the support.

Where shrubs are to be planted in groups to provide ground cover, individual plants shall be spaced as follows:

Size	Height	Spacing
Small	less than 1 m	50 - 60 cm
Medium	1 to 2 m	90 – 120 cm
Large	over 2 m	180 cm

Shrubs for borders and hedges shall have a minimum height of 0.6 m. A minimum of 2 plants per m² are to be planted to create an evenly dense area. Trees to be supplied and planted shall have a minimum height of 1.5 m. For the plant holes vegetable soil is to be used. Stabilization of freshly planted trees against wind actions shall be provided if the Engineer deems it necessary.

D.11.5 Support for Climbing Plants

Training wires shall be pegged to brickwork walling where required to support climbing plants. Wires shall be horizontal fixed to every four courses of brickwork with pegs at 1,500 mm maximum centres.

Climbing plants shall be secured to wire with sisal string as required.

D.11.6 Irrigation

After planting of native tree and shrub species they shall be irrigated regularly until hand over to the Employer.

Grassed areas shall be irrigated immediately after planting and regularly thereafter until handing over. Watering of grass shall preferably be by night time sprinkler system. If watering is carried out during the daytime the area should be flooded.

D.11.7 Maintenance

All new plants and grassed areas shall be protected to prevent damage from workmen, builders plant and equipment and animals, by the use of temporary fencing or other suitable means. All new plants and grassing shall be maintained for not less than 12 months after planting. This shall take the form of irrigation, restaking, pruning, weeding, tilling, etc. to ensure sufficient growth is achieved by all plants up to hand over to the satisfaction of the Engineer.

Once grassed areas are sufficiently established they shall be kept cut or mown to provide a uniform depth growth. Edges of grassed areas shall be trimmed as necessary.

D.11.8 Replacement

Growth of shrubs, trees and grass shall be guaranteed for one year from the day of planting. Any trees, shrubs or areas of grass which fail to show satisfactory growth or that wither and die shall be replaced by the Contractor.

The responsibility for the irrigation and maintenance of these replacement plants shall remain with the Contractor until such time as they exhibit satisfactory growth.

D.11.9 Dressing of Topsoil

Prior to planting of lawn, shrubs or trees, the topsoil shall receive a dressing of chemical fertilizer or manure approved by the Engineer at a rate of 7.5 kg/m². As minimum requirements, dressing of topsoil shall be done with lime, potash and super-phosphate, as applicable. After being spread uniformly on the surface the manure shall be thoroughly mixed into the top soil.

Dressing of topsoil shall only be carried out after watering and raining. The surface of the soil shall be kept wet until fertilizers have dissolved.

D.12. Inspection and Testing of Civil Works

D.12.1 Testing of Earthworks

D.12.1.1 General

The Contractor shall furnish all equipment and materials necessary for collecting samples and carry out field laboratory tests on materials for earthworks. Laboratory equipment shall be housed in a suitable building on Site, which shall also incorporate adequate space for the storage of field test equipment.

D.12.1.2 Main Tests and Standards

The Contractor shall carry out all tests in accordance with local and international standards. For the below tests the following DIN standards shall apply:

- DIN 18121 Moisture Test
- DIN 18122 Consistency Test
- DIN 18123 Grading Tests
- DIN 18124 Density Test (solid volume without voids)
- DIN 18125 Density Test for Soils (including voids)
- DIN 18127 Proctor Test

- DIN 18134 Loading Test

D.12.1.3 Compaction of Soils

The Contractor shall carry out the compaction to safely achieve the specified dry density and control soil compaction during backfilling and filling operation.

Where the sub grade or layers of soil material require being moisture conditioned before compaction, the Contractor shall uniformly apply water to the sub grade or layer of soil to attain the optimum moisture content required. The application of water shall be carried out in a manner to prevent free water appearing on surface during compaction operations.

The Contractor shall replace soil material that is too wet for compaction to the specified densities.

D.12.1.4 Testing of Compaction

The Contractor shall inspect, perform and report all testing and retesting as to ensure that the works conform to the specified requirements. In order to test the degree of compaction, the Contractor shall carry out field density tests in accordance to DIN 18127 or BS 1377.

For each compacted backfill of trench the required number of field density tests to ensure compliance with specification shall not be less than three passing tests between each 2 chambers or 100 linear meters (whichever is smaller) of filled and compacted trench.

If, in the opinion of the Engineer, the sub grade, backfill and fill layers have been placed and compacted to densities below the specified limits, the Contractor shall provide additional compaction and testing until satisfactory results are attained or remove certain sections of the work and reconstruct them according to the Specifications.

All holes made for the purpose of tests shall be restored by the Contractor to conform to the characteristics of the adjacent layers.

The compaction required for various fills shall be as follows:

		% of Max. Density
Item of Works	Materials Prescribed	acc. to ASTM D698

Backfill for over-excavation Granular material 100 % Formation and bedding layers Fine granular material 95 % Crushed stone supporting layers Crusher runs 95 % Final backfill of trenches under roads Fine granular material 100 % Backfill of trenches in general Fine granular material 98 % Sandy material 95 % Clayey material 93 % Backfill below structures Fine granular material 100 % Bedding compaction tests shall be performed by a Contractor (dynamic plate) and the Contractor shall keep records for each section in minimum two locations. The compaction of the final layer shall be tested by an authorised institution with a static plate. The minimum conditions for compaction of the road final layer are determined by the following prescribed compressibility modules:

- ≥ 100 MPa for main roads;
- ≥ 80 MPa for municipal roads;
- ≥ 40 MPa for other roads.

D.12.2 Inspection and Testing of Structural Works

D.12.2.1 Inspection prior to Commencement of Works

Buildings and other structures in close proximity to the Construction Site that might be damaged by excavation or other work shall be inspected before work is commenced. All parties concerned shall be invited by the Contractor to participate in the inspection.

The Engineer and the Contractor shall make the inspection jointly and the Contractor shall set out an inspection report, including “preconstruction photos”. The report shall describe the conditions of the buildings, roads, footpaths etc. in question.

Any failure or damage caused by excavation or other works, shall be repaired and maintained by the Contractor without any delay.

D.12.2.2 Testing of Concrete Works

D.12.2.2.1 Concrete Works, Test Certificates

Unless otherwise directed by the Engineer, the Contractor shall supply and submit to the Engineer:

- Manufacturers test sheets with each consignment of cement and admixtures certifying the compliance with the relevant standards;
- Certification of the calibration of weighing and dispensing equipment on the batch mixing plant;
- The certified test results for all tests carried out on aggregates, water fresh and hardened concrete.

In case of doubts, new tests shall be executed upon the Engineer’s direction at the Contractor’s expense.

D.12.2.2.2 Concrete Works, Inspections

No concrete shall be placed until the Engineer has inspected and approved the surfaces upon which the concrete is placed the formwork and the reinforcing steel.

If requested by the Engineer to do so, the Contractor shall institute a “pour card” system in which a card is made out for each lift of concrete and is initialled by the Contractor and the Engineer confirming that the inspections have been carried out.

The “pour card” shall include spaces to identify the concrete being placed and to signify the completion of the inspections by the Contractor and the Engineer in regard to:

- Preparation of surfaces on which concrete is to be placed;
- Formwork;
- Reinforcement;
- Readiness for concrete placing;
- Striking time of formwork;
- Inspection after removal of framework (remedial work directed);
- Curing procedures;
- Completion of remedial work (if any);
- With each delivery of concrete, the Contractor shall be obliged to provide a shipping document for each round of transport with information on the type of concrete and the quantities of components used (concrete recipe).

D.12.2.2.3 Sampling and Testing of Aggregates

The Contractor shall sample and carry out mechanical analysis of the fine aggregates and each normal size of coarse aggregate in use, employing the method described in ISO 19595 and ISO 20290 at least once a week when concreting is in progress and at such more frequent intervals as the Engineer may require.

The grading of all aggregates shall be within specified limits. Should the fraction of aggregate retained on any sieve differ from the corresponding fraction of aggregate in the approved mix by more than 5 % of the total quantity of fine and coarse aggregate, the Engineer may instruct the Contractor to alter the relative portions of the aggregates in the mix to allow for such differences.

D.12.2.2.4 Sampling and Testing of Concrete

The Contractor shall provide the equipment necessary to determine the compacting factor of freshly mixed concrete at each place where concrete is being prepared and shall determine the compacting factor of the freshly mixed concrete by the method described in DIN 1048 on each location where a set of test cubes is made and not less than once a day or as the Engineer may direct.

Unless particularly specified, for each grade of concrete works test cubes shall be made whenever required by the Engineer but not less frequently than one set of cubes per 25 m³ or part thereof concreted at least one set per day.

Each set of cubes (six cubes per set) shall be made from a single sample of a concrete batch taken by random. Each three cubes shall be tested 7 and 28 days after manufacture.

When requested by the Engineer, additional set of cubes shall be made for testing 3 days after manufacture. Test reports shall be submitted to the Engineer in duplicate.

Concrete consistency testing shall be performed at the place of manufacture and at the site of concrete placement in the presence of the Engineer. This type of testing shall be performed with a "slump" test. The Contractor shall be obliged to provide testing equipment.

D.12.2.2.5 Compliance with specified Requirements

When determining a concrete mix design such design shall be deemed satisfactory provided that:

- a) The average 28 days strength f_{cm} determined from every group of three (3) consecutive test cubes (edge length 150 mm) is not less than $f_{ck, cube} + 4 \text{ N/mm}^2$ (i.e. for grade C 25 / 30 concrete the average strength is not less than 34 N/mm²);
- b) The minimum strength of any cube must be f_{ci} (i.e. for grade C 20 / 25 concrete the strength of each cube is not less than 30 N/mm² minimum);

If one cube result fails to meet the second requirement (b) the result may be considered to represent only the particular cube, provided that the average strength of the group satisfies requirement (a);

If more than one cube in a group fails to meet the second requirement (b) then all the concrete in all the batch shall be deemed not to comply with strength requirements;

During execution of the concrete works such concrete shall be deemed satisfactory provided that:

- a) The average 28 days strength f_{cm} determined from every group of four (4) consecutive test cubes is not less than $f_{ck, cube}$ (i.e. for grade C 25 / 30 concrete the average strength is not less than 30 N/mm²).
- b) The minimum strength of any individual cube f_{ci} is not less than $f_{ck, cube} - 4 \text{ N/mm}^2$. (i.e. for grade C 25 / 30 concrete the strength of each cube is not less than 26 N/mm²).

If one cube result fails to meet the second requirement (d), the result may be considered to represent only the particular batch of concrete from which the cube was taken, provided that the average strength of the group satisfies the first requirement (c).

If more than one cube in a group fails to meet the second requirement (d) or if the average strength of any group of four (4) consecutive test cubes fails to meet the first requirement (c), then all the concrete in all the batches represented by such cubes shall be deemed not to comply with strength requirements

D.12.2.2.6 Non-compliance with specified Requirements

When the average strength of four consecutive test cubes fails to meet the first requirement, no further concrete from that mix shall be placed in the work and the Contractor shall establish the cause of the failure and apply such remedies as are necessary.

The Contractor shall demonstrate by trial mixes and test cube results that the revised mix is in accordance with the specified requirements.

The Contractor shall, within 24 hours of the date of testing, make proposals for agreement with the Engineer about actions to be taken in respect of any concrete represented by the test cubes which fail to meet either of the requirements. These proposals may include, but shall not be limited to, cutting and testing cores.

Concrete, which is ultimately not found to comply with any of the requirements of the Specification, shall be broken out and replaced or otherwise dealt with as instructed by the Engineer.

The Engineer may order additional cement to be added to the mix immediately. The mixes used may also be changed whenever, in the opinion of the Engineer, such change is necessary or desirable to secure the required workability, density, tightness, surface finish and strength.

D.12.2.2.7 Cutting and Testing of Core Samples

As and where directed by the Engineer, cylindrical core samples shall be taken normal to the surface of the hardened concrete for examination and testing.

The procedure for drilling, examination, measurement and testing shall be in accordance with DIN 1048.

Prior to the preparation for testing, the specimen shall be made available for examination by the Engineer.

If the crushing strength of the specimen determined in accordance to DIN 1048 is less than the characteristic strength at 28 days for the grade requirements in other aspects, that concrete in that part of the Works of which it is a sample shall be considered not to comply with the specified requirements.

D.12.3 Testing Structures for Watertightness

Tightness test shall be carried out before any backfill around the structure subject to test takes place. All outside surfaces of the structure must be cleaned, smoothened and be completely visible and accessible. Each tank of a multi-tank reservoir shall be subject to a separate test.

Water filling of the structure shall start during daylight to allow for continuous inspection during filling. The structure shall be filled up to the maximum operating water level or as otherwise instructed by the Engineer.

Concrete structures or clay sealed structures shall be maintained full over a period of 7 consecutive days prior to the test to achieve saturation of the lay and concrete exposed to water.

For structures completely made of steel such saturation period is not required, and the Contractor shall maintain the tank / reservoir full one day prior to start of test.

A visual check of all concrete wall surfaces shall then take place. If such inspection does not identify visible leakages or wet spots, the test can continue. If such inspection however identifies leakages and wet spots, the test will be terminated and the Contractor shall proceed with repairs of the respective parts as instructed by the Engineer.

After having successfully passed the visual inspection of the external surfaces, the main test shall be undertaken. The main test shall last 48 hours. During that period of 48 consecutive hours the structure shall be tightly sealed. Water level shall be measured at the beginning and end of the main test period. If water level drop does not exceed one (1) cm or 0,3 % of the testing water depth, whichever is less, the test shall be considered as successful. The Contractor shall supply all water required for the test.

From the start of filing until completion of the test, the Contractor shall monitor the water level decrease through precision levelling as directed by the Engineer.

From start of filing until completion of the test, the Contractor shall monitor the settlements of the tanks through precision leveling on the benchmarks grouted into the concrete as directed by the Engineer, particularly at the four corners of rectangular tanks and every 90° at the circumference of round tanks.

Frequency of levelling and recording formats shall be as instructed by the Engineer.

D.12.4 Tests on Completion for Civil Works

In the event tests carried out earlier on the respective parts of the Works have not been successful or if necessary to proof the tightness between two sections of the Works that have been tested before separately additional Tests on Completion shall be carried for any such parts of the Works.

D.12.5 Site Testing

D.12.5.1 General

Site testing includes for both tests during installation and tests at completion. The Contractor shall prepare and submit to the Engineer a comprehensive and detailed site testing programme of all parts of the Works subject to Site testing. This programme shall be submitted to the Engineer one month before start of erection / installation and be reviewed and updated as may be required from time to time.

D.12.5.2 Composite Hydraulic Systems subject to Test during Installation

Site testing includes tests during construction and installation, Pre-commissioning and Commissioning.

All joints, pipe foundations and the like shall be inspected during testing and pressure shall be maintained until such inspections are completed and as specified by EN 805 for the duration of testing, which ever lasts longer.

In the event that pressure loss encountered during test is higher than acceptable and/or any visible leak occurs or any foundation or puddle flange is found to have moved or cracked or appears damaged in any way, or if any pipe barrel or flange shows deformation, the test shall be declared as being unsuccessful.

Technical Specifications

Pipeline Construction Work

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E.1. Static Calculation of Pipelines

The static calculation shall be carried out in accordance to applicable standards.

The static calculation of sewer pipes shall be carried out in accordance to EN 1295-1 and/or ATV- DVWK A 127 “Static Calculation of Drains and Sewers” or similar technical guidelines.

Prior to the procurement of pipes, the Contractor submits a static calculation for each pipe material, for each represented pipe diameter, for all existing pipe depth intervals (with a range of 0.5 m) for different soil layers and other conditions that may vary due to working methods, etc.

The calculation shall be systematised and presented in a format that indicates:

- strength on transverse loading;
- criteria on cracks:
- resistance against forces arising from fabrication, transportation, storage and application of the concrete pipes and
- soil conditions and location of the pipes. The followings details shall be indicated for each diameter of pipe to be used in the Works.
- the spigot and socket;
- circumference of the sealing ring in non-stretched position;
- thickness and shape of the sealing ring;
- the allowable angular deviation;
- the type of bedding required for the different loading and soil conditions;
- the type of pipe surround required for the different loading and soil conditions.

The calculations must be approved by the Engineer before production or ordering of pipes shall be executed. The Contractor is fully responsible for his enclosed calculations.

E.2. Laying of Pipelines and Installation of Pipeworks

E.2.1 Definitions

The following words or expressions shall have the meanings hereby assigned to them except where the context otherwise requires:

”Pipeline” shall mean a line of pipes having an appreciable length; it may have branch lines; it does not include piping system such as process piping system within factories or treatment plant;

”Pipework” shall mean all pipes excluded from the definition of pipeline;

”Pipes” shall mean straight tubes having plan ends or ends shaped to form joints;

”Pressure pipeline” shall mean pipelines, in which the nominal internal working pressure exceeds 0,3 bar and such other pipework as may be designated;

”Gravity pipeline” shall mean a pipeline, in which the liquid being conveyed through the pipe is geared by the force of gravity only;

“Sewer” shall mean the pipelines draining wastewater and/or storm/rain water;

“Sewerage system” shall mean all the pipelines, chambers, pumping stations etc., which comprise complete system which drains wastewater to a treatment plant or which drains storm/rain water;

“Regime or working pressure” shall mean the pressure necessary in a hydraulic system to obtain the normal operating conditions;

“Fittings” shall mean bends, junctions or joints, reducers, tapers, joint adapters, couplings and similar items which are not joints or flow control equipment;

“Internal” shall mean those parts of pipes and fittings, which are to be in contact with the liquid being conveyed;

“Flexible joints” shall mean joints made with factory made joint materials, loose collars, rubber joint rings and the like, which permit angular deflection between adjacent pipes;

“Chambers” shall mean structures on the pipeline that can house pipes, fittings, valves, including fittings through chamber walls;

“Manhole” shall mean a structure on the pipe with a cover, where access to the pipe is possible;

“Wastewater” or “sewage” shall mean polluted water, discharged into a sewerage system by domestic and industrial sources;

“Sewerage system” shall mean all the pipelines, manholes, chambers, pumping stations etc., which form the complete system which leads untreated waste water from houses / industries to a treatment plant;

“Rain or storm water” shall mean water that originates during precipitation events, runs off;

“Sludge” shall mean wastewater with high solid content (above about 10 g/l);

“Faecal sludge” shall mean sludge that originates from septic tanks or pit latrines.

E.2.2 Ruling Standards

All design, facilities, materials and workmanship shall comply with the relevant latest ISO, EN or equivalent international and local standards and codes of practice. Main applicable standards are, but shall not be limited by the following:

- EN 805 Water supply - Requirements for systems and components outside buildings;
- EN 752 Drain and sewer systems outside buildings;
- EN 476 General requirements for components used in discharge pipes, drains and sewers for gravity systems;
- EN 1671 Pressure sewerage systems outside buildings;
- EN 1610 Construction and testing of drains and sewers;
- EN 1295-1 Structural design of buried pipelines under various conditions of loading - Part 1: General requirements;
- ISO 13470 Trenchless applications of ductile iron pipes systems — Product design and installation;
- ISO 11296-3 Plastics piping systems for renovation of underground non-pressure drainage and sewerage networks — Part 3: Lining with close-fit pipes;
- EN 124 Gully tops and chamber tops for vehicular and pedestrian areas – Design requirements, type testing, marking, quality control;
- EN 1092 Flanges and their joints: Circular flanges for pipes, valves, fittings and accessories, PN designated;

- EN 12889 Trenchless construction and testing of drains and sewers;
- EN 13380 General requirements for components used for renovation and repair of drain and sewer systems outside buildings;
- ISO 4633 Rubber seals - Joint rings for water supply, drainage and sewerage pipelines - Specification for materials;
- EN 681 Elastomeric seals - Material requirements for pipe joint seals used in water and drainage applications;
- EN61386 Conduit systems for cable management.

Wherever a national specification, technical standard, building, construction and environmental regulation is more restrictive than the specific standards listed in these specifications, the national standard or regulation shall take precedence.

The materials and construction must comply with the applicable standards (as last amended), which were in force on the thirty-first day of December of the year preceding the date of the tender, unless a recent amendment is listed below or must comply with official standards, approved by Engineer which, in the opinion of the Engineer, do not require more than the appropriate standards specified herein. Where the applicable standard requires a certificate for the customer, at his request, stating that the purchased materials are in accordance with the standard, the Contractor will obtain a certificate and forward it to the Engineer.

E.2.3 Pipe, Fittings, Joints and Valves – General

E.2.3.1 Scope

Pipe laying works, as specified hereunder, shall include the supply, laying and testing of pipes including manholes, fittings, joints, accessories and house connections. The bid prices shall fully include the value of works described under the several items and shall cover the cost of all labour, subsidence, travelling, supplies, materials, fittings, tools, equipment, temporary works, testing, re-testing (if applicable), watching, lightening, pumping, overhead charges and any other expenses whatsoever together with all risks, liabilities and obligations set forth or implied in the Contract Documents.

Flexibility shall be provided in the pipework at joints in the main structures to allow differential settlement and thermal stresses which shall not be transferred to the anchor blocks. Flexible joint or collars and cut pipes shall also be incorporated in pipework where necessary. The pipework system shall be so designed to ensure the anchorage at blank ends, bends, tees and valves may be kept to a minimum. The Contractor shall indicate on his detailed drawings the blocks required to anchor pipework supplied by him.

E.2.3.2 Quality of Materials

All pipes, specials, fittings, valves, accessories and all materials and other equipment supplied under the Contract shall be new and shall be manufactured in accordance with the latest relevant local and International Standards.

The Contractor shall submit documentation on the details of the delivered goods. These documents shall bear the stamp and the signature of the manufacturer. For all items of supply the Contractor shall submit to the Engineer a certificate of compliance with the specified Standard. Where other Standards are proposed, they shall be equal or superior to the relevant International and/or EN Standard.

According to these specifications, the Contractor should submit the following documents for pipes and equipment: (i) Certificate of technical inspection of goods: Certificate of technical inspection performed by the manufacturer for all pipes, fittings, special parts, pre-manufactured construction parts, machinery, etc., or all necessary documentation

required for technical acceptance. (ii) Data: a) Manufacturer's certificate in accordance with the general specifications for pipe equipment. b) Samples and all details related to all cast and metal works. c) Samples and data on specifications for all protective coatings and sealants. d) Catalogs with pipe manufacturer's instructions on handling, installation and testing. e) Samples, specification data, manuals for installation, commissioning and maintenance of all machinery.

All documents submitted by the Contractor under this Section will be submitted in English and local language in accordance with the requirements of the technical acceptance procedure. Pipe and fittings materials shall be of the best quality of the class most suitable for working under the conditions specified and shall withstand traffic loads, operating pressure, corrosion and abrasion, and the variation of temperature and climatic conditions without distortion or deterioration or the setting of undue stresses in any part of the works and without affecting the strength or the suitability of the various parts for the work which they have to perform.

Where corrosion or abrasion may be expected from contact with water, sediments or from any other cause, the Contractor shall supply suitably resistant materials.

Any material showing signs of corrosion, distortion or pitting before expiry of the Defects Notification Period shall be replaced with material approved by the Engineer, at the Contractor's own expense.

E.2.3.3 Marking

All pipes, fittings, specials, valves, accessories and other important components shall be permanently and legibly marked in such a way that the marking does not initiate cracks or other types of failure and that normal storage, weathering handling, installation and use shall not affect the legibility of the marking.

The marking shall display the following information:

- Manufacturer's name or mark;
- Material identification such as ductile iron;
- Material grade;
- Identification of the date of manufacture;
- DN and/or outside diameter and wall thickness;
- PN rating when applicable;
- Reference to relevant Standard.

E.2.3.4 Supply of Materials

Supply of material, as specified hereunder, shall include the transport from the Manufacturer's plant to the Site, handling, loading, unloading, intermediate storage and storage beside the trench in accordance with the supplier's instructions and good workmanship.

All materials shall be supplied from approved manufacturers only. The Contractor is requested to submit a list of suppliers that he intends to use, together with his bid.

The Contractor shall submit for the approval of the Engineer before ordering of materials, all information and data listed herein and all additional information required to evaluate the compliance of the proposed materials with the Contract. Data to be submitted shall include but is not limited to:

1. Catalogue data consisting of specifications, illustrations and a parts schedule that identifies the materials to be used for the various components and accessories. The illustrations shall be in sufficient detail to serve as a guide for assembly and disassembly;

2. Standard to which the item is manufactured, details of specials, adapters, fittings and joints;
3. Complete assembly drawings of fittings etc. with clearly marked dimensions. This information shall be in sufficient detail to serve as a guide for assembly and disassembly and for ordering parts;
4. Weight of all component parts;
5. Tabulated pipe schedule, which shall include the following information for all pipe and fittings: dimensions, thickness, lengths, working pressure, shape, weight, class, tolerance limits and quality;
6. Coating and lining methods;
7. Manufacturer's instructions for transporting, unloading, storing and installing pipes, fitting and other pipe accessories.

No material to be supplied under this contract shall be shipped to the Site until all submittals have been approved.

Uniformity of materials shall be maintained throughout the manufacturing process for each pipe size to the end, so that the test samples are representative. All supplies shall be new; second hand material will be rejected.

Nomenclature, classification, symbols, conditions of manufacturing, characteristics and tolerances, conditions for the preparation of specimen, test rules, identification labels and acceptance clauses of pipes and pipe-fittings must conform to the latest relevant local and International Standards.

Only materials approved and accepted by the Engineer shall be supplied and installed. The Contractor must ensure that the materials and equipment to be used are in full compliance with the specifications. The Contractor may make only one submission regarding a particular piece of equipment or type of material, unless special instructions are given by the Engineer. Other submissions will not be allowed unless the proposed supplier is officially rejected. If it is necessary to replace the proposed supplier / manufacturer during the contract, approval must be obtained, but this approval will only be given in exceptional circumstances. Materials which are rejected shall immediately be removed from the Site at the cost of the Contractor.

Pipes shall be ordered in the maximum lengths available to minimize the number of joints. The Contractor shall be responsible for the supply of all materials in sufficient quantities and shall, prior to placing any order, especially for imported goods, ascertain the required quantities.

The Contractor may propose the use of alternative materials or equipment which is: a) of at least equal quality and performance or b) of similar quality and performance and in accordance with approved standards.

If alternative materials and equipment are proposed, the Contractor must provide comprehensive information including technical descriptions, drawings, specifications and calculations showing that the alternative materials and equipment comply with the terms of this clause. Adoption of alternative material or equipment with the prior consent of the Employer will be approved by the Engineer.

E.2.3.5 Inspection by the Engineer

The Engineer reserves the right to inspect goods prior to delivery or shipment from the suppliers factory. The Contractor shall, on request, provide all necessary facilities to the Engineer or his representative to carry out such inspection.

Inspection or approval by the Engineer of any equipment or materials shall not release the Contractor from any of his obligations under this Contract.

E.2.3.6 Method Statement

The means of storing, handling and laying, together with the chosen material and construction methods for manholes and the method for compacting the pipe surrounding and the backfilling of pipe trenches and around manholes, shall be subject to the approval of the Engineer.

At the commencement of the Contract, the Contractor shall submit for the approval of the Engineer a method statement detailing his proposal for pipe laying and related activities at the Site. The method statement shall include: a) location, size and security arrangements of all proposed storage areas for pipes;

- b) methods of loading, off-loading and transporting pipes and precast concrete sections from the point of production or point of importation to the storage area;
- c) methods of loading, transporting and stringing out of pipes from the storage area to the pipeline routes;
- d) method of excavation of pipe trenches including plant to be used and methods of trench dewatering to be employed;
- e) material to be used for bedding and surrounding of pipes and backfilling of pipe trenches together with plant to be used and methods of compaction to be employed;
- f) details of the proposed order of work incorporating the specified checks and hydraulic testing.

The methods for pipe laying, jointing, bedding and backfilling recommended by the pipe manufacturer shall be strictly adhered to. In cases of conflicts between the manufacturer's recommended methods and this Specification, the decision of the Engineer will prevail.

E.2.4 Pipes, Fittings and Joints – Water Supply

E.2.4.1 Potable Water Certification

All pipe and coating materials for water distribution pipes shall not contain any ingredients that might migrate into water in amounts that are considered to be toxic or otherwise dangerous to health. Compliance with this requirement shall be certified for each of the various kinds of materials by independent institutions approved by the Engineer.

Joint lubricants for sliding joints used for jointing water supply pipes shall not impart to water taste or colour, shall not have any effect known to be injurious to health and shall be resistant to bacterial growth.

E.2.4.2 Toxic Materials

The Contractor shall not import or use any toxic or poisonous grouts for use in piping, its accessories, lining, sealing, etc., or in various kinds of concrete, soils or whatsoever.

E.2.5 Pipes, Fittings and Joints - Sewer

E.2.5.1 General Requirements

Laying shall be in accordance with the manufacture's recommendations.

All non-flanged sewer pipes shall have a gasket-type joint used in conjunction with an integral bell which shall be a homogeneous part of the pipe.

E.2.5.2 Gravity Sewers

Unless otherwise specified in the individual specifications, the minimum stiffness of pipes and fittings should be SN 8 (8 kN / m²), in accordance with EN ISO 9969 which is in accordance with the layer thicknesses above the pipe protection layer of 0.8 m.

E.2.5.3 Internal Lining of Ductile Iron and Steel Pipes for Wastewater

Ductile iron and steel pipes for sewage have to be lined with an inner sulphate resistant cement lining according to EN 10928 and DIN 2880.

E.2.5.4 Pressure Sewers

If not otherwise specified in the particular specifications, all supplied and installed pressure sewer pipes, fittings and joints shall be at least PFA = 6 bars.

E.2.6 Handling, Storage and Stringing of Pipes

E.2.6.1 Transport and Handling of Pipes

Shipping, packaging and protection of material and equipment shall be in accordance with the manufacturer's recommendations and approved international Standards. Any vehicle on which pipes are to be transported shall have a body of such length that the pipes do not overhang. The stacking height for the various items shall be as recommended by the manufacturer and approved by the Engineer but should not exceed 2,0 m for thermoplastic pipes. Each load shall be secured by ropes or other lashing arrangement so that the pipes do not move or chafe and suitable padding shall be used to ensure that the pipe is not damaged by these lashings. Pipe specials shall be supported by sandbags or other padding and lashed down as described above so that they are not damaged during transport.

The Contractor shall be responsible for obtaining all necessary permits for transporting the pipes. Wherever necessary, the Contractor shall ensure that any weight restrictions on public roads are not exceeded. The Contractor shall be responsible for making good any damage caused to these roads.

When pipes are collected from a storage site, the Contractor shall secure the remaining pipes against slippage. When a storage site is emptied of materials the Contractor shall clean the site and any access road and reinstate both to their original condition.

Pipes, fittings and appurtenances shall be handled with utmost care in such a way that damage is avoided. The Contractor shall provide appropriate machinery for loading and unloading (e.g. cranes, forklift with wide forks, etc.) and other appliance approved by the Engineer wherever it is necessary to lift or lower pipes or pipe specials. All equipment necessary for loading, transport to construction sites or storage sites and unloading shall be supplied by the Contractor.

Pipes shall only be lifted with straps of a material and a form which protects the pipes and their coating from damage. For the handling of pipes with external coating and lining, slings of canvas, rubber belting or special fittings shaped to fit the pipe ends shall be used. Hooks shall not be used for lifting of pipes nor shall pipes be dropped or dragged.

Under no circumstances shall pipes be dropped, be allowed to strike on another, be rolled freely, or dragged along the ground.

Pipes being transported shall be supported by timbers, sand bags or padding arranged in such a way that the pipes do not rest on their sockets but on their barrels and that adjacent pipes do not touch.

The height of the load for the various pipe diameters shall not be more than prescribed by the manufacturer and approved by the Engineer.

Ropes or other lashing arrangement shall secure each load so that the pipes do not move or chafe and suitable padding shall be used to ensure that the pipe coating is not damaged by these lashings.

The Contractor shall check the pipes for any visible defects or damage and notify the Engineer if any are found. The Contractor shall be responsible for making good any damage or defect to the approval of the Engineer.

The pipes shall be strung consecutively along the working width on timbers or similar, with at least two per pipe, to avoid damaging or fouling the pipes. The pipes shall be strung in such a way that the normal use of the surrounding areas is disturbed as little as possible. Pipes shall be secured against rolling. When stringing pipes with diameter tolerance marks, only ends with the same mark shall abut.

E.2.6.2 Storage on Site

Handling and storage of material and equipment shall be in accordance with the manufacturer's recommendations and approved international Standards.

All materials provided by the Contractor shall be stored in a proper storage area subject to the approval of the Engineer. The Contractor shall construct a fenced and lockable compound in which all pipes, fittings, valves and other pipe appurtenances are to be kept, and also maintain shelters of sufficient size and capacity to store the materials and to protect them from the effects of weather always in accordance with the manufacturer's prescriptions. The Contractor shall be responsible for cleaning, levelling and enclosing the storage site and shall provide all necessary security.

Storage areas shall be carefully set out to facilitate unloading, loading and checking of materials with different consignments stacked or stored separately with identifications marks clearly visible. Storage stacks shall be arranged so that the belled sockets are at alternate ends of the stack and do not bear any load.

Pipes and fittings shall be stored raised from the ground and shall be carefully supported cushioned and wedged. Pipes shall not rest directly on one another and shall not be stacked more quantity high than that of manufacturers recommendation. Thermoplastic pipes shall be protected from high temperatures and not be exposed to direct sunlight.

Couplings and joints (and all components thereof) and other similar items shall be stored in dry and cool conditions, raised from the ground in sheds or covered areas and protected from direct sunlight and frost.

All pipes, fittings and appurtenances shall be protected from weather, including sunlight, and fouling during transport, storage and stringing. If any pipe gets fouled, it shall be cleaned before installation.

The Contractor shall at all reasonable times allow the Engineer free access to any place for inspection and testing.

The Contractor shall, at his own expense, carry out all tests he considers necessary to ensure that all pipes, fittings, valves and other appurtenances are in accordance with the Contract, on his own responsibility. The Engineer may witness such tests without incurring any responsibility for the materials.

In all cases the Contractor shall satisfy the Engineer that all material has been delivered in good and clean condition, identification markings shall be clear and stock piling shall be in approved manner.

The Contractor shall keep detailed records in a format approved by the Engineer of all pipes, fittings, valves and other pipe appurtenances, showing the quantities of each type and class which have been:

- Received by the Contractor during the course of the Works;
- Declared on delivery to be faulty, damaged or deficient, broken, damaged or lost during the course of the works;
- Found to be surplus to the requirements and held by the Contractor.

Such records shall be updated and delivered by the Contractor to the Engineer on a monthly basis.

The Contractor shall comply with the Engineer's instructions as to the disposal, repair or replacement of any pipe, fitting or valve which has been notified as being faulty, damaged or missing.

E.2.6.3 Stacking of Pipes

The Contractor shall properly stack the pipes at the Site and the stacks shall be laid out in regular pattern as prescribed by the Manufacturer. The limits of each stack shall be marked so that the movement of cranes and vehicles shall be restricted to access tracks between the stacks and the control of delivery and removal of pipes is facilitated.

Where the pipes are to be delivered and stacked on designated sites along the pipeline route, the areas where the pipes are to be stacked shall, if directed by the Engineer, be graded flat by the Contractor at his own expense to provide a firm and even surface and be kept free from loose stones, rubbish or waste liable to damage pipe coating.

Material delivered will be accepted only if proper storage provisions have been made and if equipment which was damaged during shipment is either repaired or replaced.

E.2.6.4 Distribution at the Site

In distributing the material at the site of works, each piece shall be unloaded adjacent or near to the place where it is to be laid. Rubber rings for pipe joints shall be stored and protected in an appropriate manner to prevent deterioration and loss.

The Contractor shall keep the pipe and the appurtenances clean during the progress of the work. Dirt, debris or other foreign material shall be removed from the interior of the pipe and the joints before installation.

Pipes and appurtenances shall not be strung out along the trench for more than 1 day prior to installation in the trench.

E.2.7 Pipe Laying

E.2.7.1 Routing of Pipelines

Prior to the laying of any section of the pipeline, the Contractor or his representative shall make inspection on Site together with the Engineer. The Contractor shall record these obstacles and submit to the Engineer a proposal for shifts and / or relocations. All changes to the route must be approved by the Engineer.

The Engineer reserves the right to vary or abandon any part or parts of the route of pipelines indicated on drawings and the Contractor shall lay the pipes in accordance with any such variation the Engineer may issue. The Contractor shall prepare the working drawings and shall lay the pipes in accordance with any such variation the Engineer may issue.

E.2.7.2 General Requirements for Pipe Laying

Approved works The Contractor shall lay pipes and fittings in accordance with the design, manufacturer's installation recommendations as approved by the Engineer.

The construction of open channels and trenches for pipelines shall at any time be limited to lengths previously approved by the Engineer in writing. Except with the written approval of the Engineer, work on each approved length shall be completed to the satisfaction of the Engineer before work on any new length is commenced.

Water tightness Pipes, fittings and valves shall be of indicated diameter and type of material as specified, and their joints shall be completely watertight.

Depths and slopes of routes All pipes and special parts shall be laid in accordance with the designed depths and slopes of the routes presented in the working drawings approved by the Engineer, with verification and adjustment in the field, where necessary, by the Contractor and the final approval of the Engineer. Invert levels

are to be set to a tolerance of plus or minus five (± 5) millimetres for designed slopes $\geq 5\%$, or (± 2) millimetres for slopes up to 5% .

Completed pipelines shall run straight between chambers and between any bend or any curved alignment and a uniform slope shall be accurately maintained between changes of slope to be shown on the Contractor's approved shop drawings or otherwise instructed by the Engineer.

The direction of each section between two manholes is checked from the outside by the use of a tightened thread, which is parallel to the designed pipe route and supported at maximum 7,5 m distance, and from the inside by means of rays of light (or a laser, or electric torch reflected in a mirror).

Pipe shall be laid with socket pipe ends facing in direction of laying, unless directed otherwise by the Engineer. Where a pipe is laid on a slope of 10% or greater, the laying shall start at the lower end and shall proceed upward.

The pipes shall be laid in straight lines where possible. Curves of long radius shall be obtained by applying deflection at the joints. The deflection of the joints for this purpose shall not be more than 50% of the maximum deflection as specified by the pipe manufacturer for the relevant type of joint. Where a required change of direction cannot be obtained by deflection of the joints, prefabricated bends shall be used.

Pipe repairs The Contractor at his own expense shall repair any damage of the protective coating of the pipes from any causes during the construction of the pipeline to the satisfaction of the Engineer.

Temporary protections The Contractor shall provide, install and maintain temporary protective covers or plugs to prevent water, animals or extraneous material entering pipelines. Such covers or plugs shall not be permanently removed until immediately prior to jointing the relevant pipe or fitting.

At the end of each day's work a strong wooden plug or iron disk shall be firmly fixed in each open end in order to prevent any foreign material to enter the laid pipe.

E.2.7.3 Specific Requirements for Sewers

Protection against Corrosion and Abrasion Where corrosion or abrasion may be expected from contact with wastewater, sediments or from any other cause, the Contractor shall supply suitably resistant materials. Any material showing signs of corrosion or distortion before the expiry of the maintenance period shall be replaced with material approved by the Engineer, at the Contractor's own expense.

Slopes of Gravity Sewer The design criteria for the minimum slope of the sewer shall be as follows:

- for the minimum design flow, the minimum traction force (traction) shall be 1 N/mm^2 ;
- for the maximum design flow, the maximum water depth in the pipeline profile shall be 80% of the inner diameter.

Slope Tolerances of Gravity Sewers The tolerance regarding the slopes of gravity sewers shall derive from the tolerances regarding the maximum hydraulic capacity. The maximum hydraulic capacity of the built sewers shall be $\pm 5\%$ the same as the maximum hydraulic sewer capacity planned and approved by the Engineer. The Contractor should pay special attention when laying pipelines with a slope of $1 - 3\%$.

Pipe Laying of Gravity Sewers As a general principle, gravity sewers have to be built from downstream to upstream. Other methods shall not be implemented without prior approval by the Engineer.

Connection or Crossing of live Sewer Pipe The Contractor has in many cases to either intercept existing wastewater sewers or to cross live wastewater sewers by the new main collectors during the construction works.

The Contractor shall assume full responsibility for the protection of such sewer pipes during construction, whether or not they are shown on the Contractor's approved shop drawings. The Contractor shall carefully maintain, support and protect such sewers from injury of any kind. Any damage resulting from the Contractor's operations shall be repaired at his expense.

The Contractor shall not demolish or remove any existing sewers, whether indicated on the Contractor's approved shop drawings or not, unless on a specific instruction from the Engineer.

During the construction period such wastewater sewer lines being under operation have to be protected, suspended and kept at all times operative. Where such pipes have to be broken off, for instance when they cross a manhole to be newly constructed, a temporary steel or plastic connection pipe has to be laid to maintain the continuous waste water flow. Flooding of the construction pit or the new manhole shall be avoided. If the installation of such a temporary connection pipe is not feasible, the waste water flow shall be maintained by pumping over through a temporary hose pipeline.

All costs for the measures required to maintain the permanent wastewater flow in existing sewer pipes are deemed to be included.

At connection manholes e.g. where existing pipes connect to the new main collector, such existing pipes shall only be broken up and their sewage flow diverted into the new collector, once the new sewerage system has been fully completed, tested and passed all tests under dry conditions.

E.2.7.4 Replacement of Water Supply Pipe

In case of pipe replacement, unless otherwise instructed by the Engineer, the Contractor shall after obtaining the approval from the Engineer and after obtaining the excavation permit by the Employer / Engineer, follow the instructions as below:

- a) the pipe to be replaced shall be clearly located;
- b) before insulating the pipe, the Contractor is obliged, if required, to procure and install temporary pipes made of HDPE or some other material to supply the consumers along the section of replacement with water during the works;
- c) a temporary pipe as a "by-pass" will be laid above ground and fixed to the front of the buildings at a regular distance. Unless otherwise instructed by the Engineer, the diameter of the temporary pipe shall not exceed 80 mm, unless the water supply is significantly greater when it is necessary to provide a larger profile of the temporary pipe. Slabs will be laid on the temporary pipe to enable the passage of vehicles;
- d) service connections shall be shifted from the existing connection pipe to the temporary pipe;
- e) the pipe to be replaced shall be isolated from the network. The Contractor shall check in advance whether the valves / rubber balloon is functioning properly and shall install new or missing isolation valves / balloons if need arises;
- f) once the new service connections have been laid and the new main pipe tested, the new system will be put in service;
- g) the Contractor shall remove all temporary pipes, and takes the remnants of the removed pipes to the landfill for which he has the consent of the Engineer and the Employer.

Interruptions in potable water supply will be allowed for no more than 12 hours. In case of any interrupted water supply, the public affected due to the work needs to be informed minimum 3 days before commencement of the work about the works itself and the inconvenience which might occur during and after the work. Accidental interruptions of the water

supply network during the execution of works must be reported to the utility company and eliminated as soon as possible at the expense of the Contractor.

E.2.7.5 Pipe Cuttings and Matching Pipe Pieces

Cutting of Pipes For closing lengths, it may be necessary to cut pipes made of various materials. However, field cutting of the pipe and field installation of additional fittings shall be kept to a minimum. When such cutting is required it shall be done by a suitable cutting machine, recommended by the manufacturer for the particular pipe material and approved by the Engineer. Cuts shall be made in conformance with the pipe manufacturer's recommendations.

Cuts shall be smooth and perpendicular to the axis of the pipe or in the plane of the bend or other fitting. Pipes shall be cut by a method which provides a clean square profile without splitting or fracturing the pipe wall and which causes minimum damage to any protective coating and lining. Damages to coatings or linings (if any) shall be repaired.

The cut ends are then obliquely machined along the outer circumference of the pipe, and the machined end shall be exactly the same as the other spigot end of the pipe as manufactured in the factory. The spigot ends to be joined to sockets shall be chamfered. When necessary, the cut ends of pipes shall be formed to the tapers and chamfers suitable for the type of joint to be used.

The cut ends of glass-fibre-reinforced plastic shall be coated/sealed with resin, as supplied by the manufacturer, but using a pigment different from that of the pipe itself.

Where ductile pipes larger than 450 mm diameter are to be cut to form non-standard lengths, the Contractor shall comply with the manufacturer's recommendations in respect of ovality correction to the cut spigot end.

Where cut concrete pipes are used, any exposed reinforcement shall be coated/sealed with an approved epoxy resin.

Matching Pieces Matching pieces required in any section of a main or to terminate the main in chambers or other parts of the works shall be cut only after all adjacent pipes have been installed and jointed.

E.2.7.6 Laying of Pipes in Trenches

E.2.7.6.1 General provision

Installation of pipelines includes the excavation of trenches, supply, laying and jointing of pipes and fittings, construction of beddings and foundations, manholes and other structures in the line, testing, backfilling of trenches, reinstatement and commissioning.

Pipelines and chambers shall be installed according to international and local standards and pipe manufacturer's guidelines. The contractor must ensure and document that the conditions and assumptions used in the structural calculations comply with the actual conditions of soil, excavations method, cross section of the trench, compaction, materials, earth cover etc.

E.2.7.6.2 Excavation and Backfilling

Excavation shall be carried out in accordance with Section D.4.2. Backfilling shall be carried out in accordance with Section D.4.4.

Unless otherwise specified, the minimum trench width shall follow requirements as stated in EN 1610. Trenches shall be secured against the risk of collapse by adequate shoring and planking systems in accordance with EN 1610 and local regulations.

The excavation formation for pipelines shall be even and free of stones and other protrusions. The bottom of the trenches shall be levelled and prepared so that it forms a solid and uniform base along the entire length of each pipe. Holes for collecting groundwater inflows and pumping shall be provided where necessary.

The pipes shall be laid in a dry excavation. If the excavation formation lies below the groundwater level, the Contractor shall install a drainage system (collection holes and pump), in agreement with the Engineer. Drainage shall continue until all works below the groundwater level have been completed or as otherwise instructed by the Engineer.

The Contractor shall inform the Engineer sufficiently in advance when a section of trench has been prepared ready for installation of pipes or concrete foundations and ready for inspection. The Contractor shall not continue with laying of pipes, concreting or other work until the trench bottom has been inspected and approved by the Engineer.

Before being positioned, each pipe shall be thoroughly examined to ensure that it is free from defects and shall have all dirt removed from the inside thereof. The Contractor shall lay the pipe in accordance with professional practice and install all fittings, specials and adaptors as may be required for the proper execution of the works.

E.2.7.6.3 Bedding to Pipelines

Unless otherwise specified and except where concrete protection is required, pipes shall generally be laid on a well-compacted bed of approved granular material after excavation. The granular material for pipe bedding shall consist of gravel and shall fulfil the requirements of EN 1610. The particle-size distribution curves shall be in accordance with addendum B, tables for Austria, Switzerland, Germany or Netherlands. The minimum thickness of the compacted bedding material shall be:

- 0,10 m (internal diameter of pipe $\leq$ 1,0 m or for cables);
- 0,20 m (internal diameter of pipe $>$ 1,0 m).

The bedding material for plastic pipes (GRP, HDPE, PVC, PP) shall be according to the manufacturers requirements.

The bedding material for concrete and steel pipes shall consist of sand-gravel, graded 0-25 mm.

The bedding material for thermoplastic and GRP pipes shall consist of fine grained sand in the fraction 0-8 mm.

The bedding material for cable conduits and cables shall consist of sand, graded 0-4 mm.

Where pipes are jointed, bell holes of ample dimensions shall be formed in the bedding, to ensure that each pipe is uniformly supported throughout the length of its barrel and to enable joints to be made.

The granular material shall be spread over the full width of the formation and lightly compacted to a level slightly higher than the level corresponding to the underside of the pipe barrel, to allow for settlement of the pipe to the correct level.

Further granular material shall be placed in the trench, special care being taken to fill under the sides of the pipe to ensure full contact with the barrel of the pipe, but leaving the joints exposed for a length of approximately 200 mm on each side of the joint collar, sleeve or socket. The granular material shall then be compacted evenly on both sides of the pipe.

When reinforced concrete bedding is applied, the concrete layers shall be made of C16/20 concrete and applied over the entire width of the trench bottom or another defined width (according to the design) in a minimum layer thickness of 10 cm. Before making a concrete bedding at the bottom of the channel, it is necessary to place a sand bedding with a fraction of 0-16 mm and a thickness of 10 cm. Reinforced concrete slab is reinforced in two layers with the designed reinforcing mesh Q131. Slabs are made individually for each pipe with interruptions and with a designed length that ensures smooth installation and position of the coupling. After concreting, time is left for the concrete beddings to bond.

The concrete base for the pipes is placed at an appropriate slope towards the longitudinal profile of the sewer pipeline and at a depth to provide the designed elevation of the pipe level (lower point of the inner part of the pipe), taking into account the height of the ribs around the pipe.

The concrete slab as a manhole bedding is made of reinforced concrete C25/30, measuring 0.15 x 1.50 x 1.50 m with formwork to limit the width and length of the slab. It is reinforced in two layers with the Q335 reinforcement mesh.

E.2.7.6.4 Laying of Pipes

Pipes, fittings and sealing rubber gaskets shall be carefully cleaned and examined for soundness before they are lowered into the trenches or before they are installed. Spigot and socket ends of pipes shall be examined with particular care. The Contractor will label all damaged pipes and fittings and remove them from the site. Only pipes approved by Engineer can be installed. Any pipe which is damaged or has any perceptible objections will be rejected by the Engineer and replaced at the Contractor's expense.

Pipe lowering shall be carried out in a safe manner in accordance with applicable safety regulations and normal practices. The pipe shall be handled with approved equipment designed to prevent damage to the pipe and the external coating. Bare cables, chains, hooks or metal bars will not be allowed to come into contact neither with the external coating nor with the inner lining. Bitumen coated pipes shall be handled with suitable slings which do not damage neither pipe nor coating. A sufficient number of lifting machines (e.g. side booms) shall be used to ensure that the pipe is not subject to detrimental stresses.

The pipes must not be thrown into the trenches. Damaged pipes, fittings and sealing elements must not be used.

The Contractor shall, before lowering the pipe, ensure that the bottom of the trench is even and free from stones and other deleterious matter which may damage the pipe coating.

The lowering-in procedure shall ensure that the pipe is not subjected to shocks or unnecessary stresses. If a section is damaged during lowering, it shall be taken up again, repaired and relowered. Any damage which may affect the structural integrity of the pipeline shall be treated as directed by the Engineer. The Contractor shall bear all costs associated herewith.

Where possible the ends of all lowered pipeline sections shall be closed with watertight caps. The Contractor is responsible for keeping the pipeline internally clean and free from foreign matter.

Any additional excavation required after the pipe has been lowered shall only be carried out with the permission and of the Engineer.

Each pipe shall be laid accurately to line and gradient so that the finished pipeline shall be in a straight line both in horizontal and vertical planes. The Contractor shall use suitable mechanical equipment, preferably hand operated, for pushing the pipes at the joints.

Where pipelines are to be constructed in trenches the Contractor shall provide, fix and maintain at intervals not exceeding 10 m, or at such points as may be directed by the Engineer, properly painted sight rails and boning rods of predetermined measurement for the boning in of individual pipes to correct alignment. The bobbing rod shall have a horizontal shoe to rest on the invert. The sight rails shall be situated vertically above the line of pipes or immediately adjacent thereto and there shall at no time be less than three sight rails in position on each length of pipeline under construction to any gradient. Consideration will be given by the Engineer to alternative methods for controlling alignment such as laser beam instruments.

The Contractor shall keep the interior of pipes clean and free from water, dirt, stones and other foreign matter as installation proceeds, and at the end of the day's work or at other times when installation work is not proceeding the

open ends of the pipes shall be sealed off by a suitable stopper. The Contractor shall take such precautions as are necessary to prevent pipes from floating.

The pipes shall be positioned and bedded in the trenches on the compacted gravel bedding layer/or concrete bedding and jointed in an adequate manner. The jointing of all pipes shall be carried out in strict accordance with the manufacturer's instructions. All joint openings have to remain uncovered until passing the prescribed pressure test to the Engineer's satisfaction.

E.2.7.6.5 Back-filling of Excavations for Pipes or Cables

Initial Backfill

Backfilling of the excavation after laying the pipe shall not be done without the approval of the Engineer. The initial backfill (embedding) of pipes and cables after the construction of the designed bedding includes the procurement and installation of backfill material around and above the top of the pipe, with compaction of layers, manually or with appropriate machines, to the specified compaction below and around the pipe. Backfilling work around the pipe and above the top of the pipe is carried out in accordance with EN 1610.

Sand shall be used for initial backfilling of pipes in trenches. Material shall be sound, clean, uncontaminated granular material, uniformly graded and of a maximum size of particles of 20 mm and particles smaller than 0,02 mm less than 10 %. In addition, material shall be free from organic and deleterious matter and shall not contain more than 15 % by weight of clay or silt, individually or in combination.

The bedding zone below, lateral and above the pipe or cable shall be filled and carefully compacted by a method approved by the Engineer to avoid change in alignment and level of the pipes or cables. Unless otherwise specified, the same material as for the bedding shall be used.

Lateral bedding shall be formed by spreading and compacting bedding material along the entire width of the trench. Sufficient bedding material shall be provided so that the pipes or cables can have stability in the appropriate line and level. Special care must be taken to ensure that the backfill material is distributed evenly on both sides of the pipe to support the pipe properly and to avoid lateral twisting of the pipe. The difference in the level of the material on both sides of the pipe must not exceed 0.2 m.

Sufficient space shall be left to enable the pipe joints to be made, tested and inspected and the Contractor shall ensure that at least three quarters of each pipe length is fully supported. The joints of thermoplastic pipes which shall be kept exposed during the pressure test, shall be shielded with hessian or hemp cloth fixed at least 0,5 m above the top of the pipe until the final backfilling starts. Before any further filling the pipeline shall be tested and approved by the Engineer.

Unless specified otherwise for the specific pipe types, all pipes shall be covered by bedding material to a level of 0,3 m above the top of the pipes. Unless specified otherwise for the specific cable types, all cables shall be covered by bedding material to a level of 0,2 m above the top of the cables.

The pipe bedding material around and above the pipe shall be compacted in layers not thicker than 100 mm per compaction using small hand-held compaction equipment on both sides of the pipe and the layer above the pipe. Mechanical compaction of the main backfill layer directly above the protective layer of the pipe may not be commenced until a total depth of cover of at least 300 mm above the top of the pipe is reached. Each layer shall be separately compacted to a dry density not less than 95 % of maximum density obtained in Modified Proctor Test where the pipeline is under existing roads and to 90 % where the pipeline is not subject to vehicular traffic and under new roads. Site tests shall be made to prove the effectiveness of the method of compacting at intervals or as indicated in Section D.13.1.4 or as instructed by the Engineer.

General Backfill

Excavation materials that are unsuitable for backfilling shall be disposed of separately and removed from the construction site (landfill).

Materials that are unsuitable for backfilling trenches are: i) materials from marshes, swamps and ponds (of organic origin),

- ii) vegetative material, timber or similar decomposing materials,
- iii) materials subject to spontaneous combustion,
- iv) clay or soil containing excess liquid content.

Backfilling around the facilities (manholes) shall be done with the selected material from the excavation if it meets the technical requirements of the embankment. The properties of this material will be similar to those listed below for the original trench filling. The material must be compacted in layers not exceeding 20 cm. The compaction will be such that a compaction of 95% is achieved according to the standard Proctor test.

The backfilling of the trench in the pavement structure shall be done exclusively with new tampon material with the use of mechanization for layered compaction to the required degree of compaction. The final surface of the filling shall be neatly finished and adapted to the environment.

The pipe bedding must be compacted to obtain a compaction of ≥ 6 MPa. The remaining part of the backfilling up to ground level shall be placed and compacted in layers not exceeding 30 cm thick. Heavy tampers shall not be used within the layer of 30 cm above the top of pipes of diameter < 200 mm and within the layer of 50 cm above larger pipes. Under vehicular traffic areas backfilling shall be made in layers not exceeding 200 mm.

The remaining part of the trench shall be back-filled with approved selected material and shall be compacted flush with ground level in accordance with the Employer's Requirements. Trench substructure and plank shall be gradually removed in accordance with the progress of the backfilling, constantly making sure that this does not endanger the safety of the works.

The remaining part of the trench backfilling shall be done with material specified in the design and approved by the Engineer. Special care shall be taken when backfilling the trench so as not to damage the pipes and equipment of the sewer line. A sufficient amount of the protective layer of the initial filling will be applied to the joints and equipment of the sewer line before the final filling is applied. The final filling for the pipes in trenches shall be compacted to obtain a compaction of 95% according to the standard Proctor test in layers not exceeding a thickness of 30 cm. When backfilling the trenches with new buffer material (trenches in the road body), it is necessary to meet the requirements of load-bearing capacity and stability of the material in the trench, which is determined by conducting a test of the value of the compressibility module.

The compressibility module of the buffer layer, depending on the road category, should meet the following criteria:

- $M_s \geq 100$ MPa for the bedding under the main asphalt surfacing;
- $M_s \geq 80$ MPa for bedding under public asphalt roads, sidewalks and footpaths;
- $M_s \geq 60$ MPa for buffer embankment of macadam roads;
- $M_s \geq 40$ MPa for buffer embankment on unclassified macadam roads.

Testing of compaction of materials on backfilled trenches in roads will be performed by order of the Engineer.

The backfilling of the final layer of the trench, which is located in green areas, agricultural and other land, shall be done with excavated material, restoring the surface to its original condition. Excavated or borrow material used for general

back-filling, shall be free from cinders, ashes, organic matter and debris or other contamination and shall be granular and suitably graded to obtain the required compaction and shall not contain stones or crushed rock larger than 75 mm in the largest dimension. Additionally, back-fill material for trenches shall conform to the following requirements:

- Uniformity Coefficient 6 minimum;
- Plasticity Index 15 maximum;
- Liquid limit 35 maximum.

E.2.7.6.6 Selected Excavated Backfill Material

Selected material for backfilling the trench with excavated material in general case for structures and pipelines, etc., shall comprise uniform readily compactable material free from tree roots, vegetable matter, building rubbish and or other particles greater than 50 mm in size, and shall be selected from either the excavated material from trench or the suitable excavated material from road works in case the amount of material derived from excavation works is greater than the amount of material required for backfilling. Sand generated as a product of earthworks shall be accepted as selected backfill material but only for use in confined areas which are to be agreed with and approved by the Engineer. After placing in the trench, this sand must be moistened in order to achieve the appropriate degree of compaction.

Where material has to be obtained from sources outside the site of the project such material will be classed as imported selected fill.

E.2.7.6.7 Stanks to Pipeline with Granular Bedding

Stanks (which are impermeable barriers designed to prevent groundwater flow along the trench) shall be provided across the full width of the trench and for the complete depth of the bedding when pipes are laid with granular bedding or backfill, at any points where pipe trenches pass through or into impermeable strata whose permeability is lower than that of the adjacent ground so as to form a restriction to the flow of groundwater. In these cases, the stanks shall be formed so as to restore the continuity of the impermeable, or low permeability, stratum where it has been intersected by the trench excavation.

Fill between stanks shall not exceed 50 m intervals and shall be generally midway between manholes or thrust blocks.

The stank shall consist of:

- a 300 mm long plug of clay, clayey soil or other approved impermeable soil, or of a mixture of sand and bitumen, consolidated in an approved manner;
- a layer of plastic sheeting, minimum thickness 1 mm, cut to fit around the pipe across the full width of the trench and laid of the granular bedding or fill material at the natural repose angle.

All methods must form an impermeable barrier.

Bitumen shall not be used for trenches containing thermoplastic pipes.

The cost of providing stanks shall be included in the Contractor's rates for pipe laying.

E.2.7.6.8 Branch Pipe to Pipe Connections

General Requirements The connection angle between the secondary pipe and the main pipe shall be at least 30° above the horizontal. Exceptions shall have to be approved by the Engineer.

The combination of pipe reducers with the 45° branches or with the saddles is not allowed.

Connections between new Pipes If the diameter of the main pipe is lower than DN 400 mm the connection shall be implemented with a 45° degree branch.

If the main pipe diameter is equal or larger than DN 400 mm, then the connection shall be made by drilling the main pipe and installing a compatible saddle. Drilling shall be made with a specific saddle manufacturer drilling tool.

In both cases, the connection angle between the secondary pipe and the main pipe shall be at least 30° above the horizontal. Exceptions shall have to be approved by the Engineer.

The combination of pipe reducers with the 45° branches or with the saddles is not allowed.

Connection to existing Pipes If the diameter of the main pipe is lower than DN 400 mm the connection shall be implemented with a 45° degree branch. The connection angle between the secondary pipe and the main pipe shall be at least 30° above the horizontal. Exceptions shall have to be approved by the Engineer.

If the main pipe diameter is larger or equal to DN 400, then the connection shall be made by drilling the existing main pipe and installing a compatible saddle. Drilling shall be made with a specific saddle manufacturer drilling tool.

If the main pipe diameter is lower than DN 250 mm, then existing main pipe shall be cut for the installation of a 45° branch. The connection of the 45° branch shall be made with coupling adaptor(s) as required.

E.2.7.6.9 Connection to existing Pipe Works

Where the drawings indicate that a connection of any kind to be made into an existing pipeline, or whenever directed by the Engineer to make such a connection, the Contractor shall investigate and verify all such connections before start of the works to determine the material, exact diameter and level of any existing pipe to which a new pipe will be connected. When necessary the Contractor shall excavate trial holes, to ensure that the materials to be furnished under the Contract will be suitable for making the connections. Having excavated the test pit and exposed the existing pipe the Contractor is to measure the invert level of the existing pipe and its external diameter. The Contractor shall submit to the Engineer a proposal for the intended transition pieces for approval before ordering the respective accessories.

In case of pipe replacement, new pipes shall be laid on the same horizontal alignment as the old ones. Old pipes shall be removed and hauled to a site approved by the Engineer.

The Contractor shall note that the period of interruptions of the existing service pipeline shall be kept to the minimum and shall arrange to make such connections at periods agreed with the Engineer.

Before attempting any connection to the existing network, the Contractor shall in-form the Engineer and the service provider responsible for operating the network and agree on a suitable procedure for the works. The Contractor shall give at least six working days' notice to the Engineer and will be required to execute these works so as to cause minimal interference with the normal operation of the network, including night working where necessary. Extension of the Contract Period will not be granted for any delays arising out of the Contractor's failure to follow the agreed procedure. The Contractor shall submit additional shop drawings and a detailed method statement for approval by the Engineer. Cutting into the existing main pipe and effecting the interconnection shall only be made in the presence of the Engineer or Employer at the time specified by the Employer.

Cutting into the existing main pipe and installation of the connecting pipework shall be carried out efficiently and rapidly so as to reduce to a minimum the interruption of the regular operation of the network. Existing mains shall only be cut using special equipment approved by the Engineer. Under no circumstances shall oxyacetylene or electric arc cutters be used. The cut shall be perpendicular to ensure that the new pipework to be shown on the Contractor's approved shop drawings may be installed. The Contractor shall agree with the Engineer's Representative the length of existing pipework to be removed. The Contractor shall take every care to avoid any dirt or extraneous material entering existing pipes. The Contractor shall have available at the site of the connection an efficient de-watering pump before commencing any cut into the existing main in order that excavation remains dry at all times and to reduce the risk of

dirty or contaminated water entering the existing distribution system. The work shall be carried out in a clean and efficient manner. Sufficient length of hoses shall be provided to dispose the water to safe places. The Employer will in general wish to re-commission the pipeline as soon as possible after its installation and will carry out an inspection to detect any evidence of leakage; any remedial work necessary to eliminate leakage shall be carried out by the Contractor. No pipework shall be covered or backfilled until the Engineer's Representative is satisfied that the interconnection is free from any leakage.

The new pipe and connection together with any adjacent portion of the existing pipeline, which may have been disturbed by the Contractor, shall be tested for leakage. Any existing pipe failing to pass the test due to damage occurring during the connection operation shall be removed and replaced by the Contractor. The test shall be repeated until a satisfactory test obtained. Any additional cleaning and disinfection procedures required in respect of the connection shall be performed by the Contractor at no additional cost.

E.2.7.6.10 Thrust (Anchor) Blocks

Except where welded steel pipelines or self-anchoring joints are used, concrete blocks (anchors) shall be provided to pressure pipelines at the points where following thrusts are produced or where ordered by the Engineer or indicated on the Contractor's approved shop drawings:

- changes in direction (bends deflecting 11,25° or more)
- changes in nominal diameter (reducers);
- branching (tees);
- pipeline ends (blank flanges) whether permanent or temporary as during testing of pipeline sections.

At all the above points the Contractor shall construct a thrust anchor block. Thrusts blocks shall be of reinforced concrete class C20/25 or mass concrete C12/15 to the dimensions appropriate for the purpose of the pipe, or as ordered by the Engineer. Any additional excavation required to accommodate thrust blocks shall be carried out after the bend or branch is in position and the thrust face shall be trimmed back to remove all loose or weathered material immediately prior to concreting. Thrust blocks shall be extended from the fitting to solid undisturbed ground, shall be suitably reinforced, if necessary, and shall be installed so that all joints are accessible for repair. The concrete backfill to the excavation shall be placed the same day as any additional excavation for the thrust block or anchorage is carried out. All concrete thrust blocks and collars shall be allowed to cure for at least 7 days before backfilling or bringing thrust to the blocks.

Thrust forces and shaping and siting of the thrust anchor blocks and collars shall conform to the field test pressure and shall be calculated in the Final Design considering the prevailing soil bearing capacity.

Where it is not possible to brace against undisturbed soil, suitable fenders shall be arranged as directed by the Engineer.

For concrete chambers, the static requirements necessary for the safe transfer of thrust into the natural soil are defined by the Final Design.

For concrete shafts,

Thrust anchor blocks shall be allowed to develop adequate strength before any internal pressure is applied to the pipeline.

Plastic pipes shall be wrapped with a layer of plastic sheeting before being surrounded by concrete.

E.2.7.6.11 Support Anchor Blocks

Movement of non-flanged or not welded pipelines or without thrust resistant joints, must be prevented by concrete support anchor blocks. The Contractor shall design, supply and construct all necessary support anchor blocks.

Anchor blocks shall be provided for all horizontal or vertical bending of pipeline. The quality of concrete shall be of class C 25/30. The structural analyses for anchor blocks shall be prepared by the Contractor and approved by the Engineer. Thrust forces, calculation and sizing of anchor blocks shall be taken from the manufacturer's instructions for a particular pipe material, whereas the pipe pressure is identical with the actual field test pressure.

Anchor blocks will also be required in water soaked soils to prevent an up-drift of pipes when empty in accordance to Section E.2.7.6.12.

The Contractor shall determine the size and weight of the concrete anchor block and its spacing and obtain approval from the Engineer.

Plastic pipes shall be wrapped with a layer of plastic sheeting before being surrounded by concrete.

Support blocks must be cast between the fitting, which is to be supported, and the undisturbed wall of the trench. The concrete must be placed around the fitting in such way that the couplings are not covered or fixed by it, to allow flexibility and to provide access to the collars for replacing when necessary. Anchor blocks against up-drift shall be cast under the pipeline and the pipe must be fixed with a clamp onto the block as directed by the Engineer. Support block shall be placed to support any piece of equipment, as well as tees, bends, or other fittings as directed by the Engineer. Support block shall be placed in such manner to allow easy access for removal of valves, fittings etc. Before casting concrete, bituminous felt must be wrapped around the fitting at the interface between concrete and the fitting. Where required, anchor clamps shall be provided by the Contractor and deemed to be included in the unit prices for anchor blocks.

E.2.7.6.12 Securing against Uplift

Pipelines shall be secured against uplift by hydraulic pressure. All static calculations shall be made for the empty pipe.

Securing against uplift may be accomplished by backfilling with material or concrete or by anchoring which should be defined by the Final Design.

E.2.7.6.13 Concrete Protection to Pipelines

Where required, pipelines, and notably plastic pipelines running under drain channels, culverts, streams or roads, shall be encased in concrete, reinforced concrete pipes of strength class C25/30 or steel pipes in full length. The inner diameter of the concrete pipe shall be sufficient for the undisturbed installation of the plastic pipe. Installation of sewer pipes inside the protective pipe must be done with supporting structures. It is not allowed to lay the sewer pipe on the bottom of the protective pipe. When the installation is completed, the protective pipe must be filled with a suitable liquid cement mortar. In special cases (according to the requirements of the competent road authority) the Contractor will act according to that request.

Where a pipeline crosses over drains or other utilities, and where the soil cover is not sufficient and concrete encasement is not advisable, a reinforced concrete slab shall be placed 200 mm above the top of the pipe. The slab may not be cast before the backfilled ground has been compacted. The concrete protection to the pipelines shall be either bed or surround and shall be of concrete C20/25 along such lengths as are shown on the approved drawings or ordered by the Engineer.

After the pipeline has been tested by the Contractor and approved by the Engineer the pipe outer face shall be thoroughly cleaned. Concrete C20/25 shall be carefully placed and compacted thereon to avoid disturbing the pipes or joints until the appropriate profile for the type of protection required has been reached.

The concrete protection shall be placed to the full width of the trench and never less than 150 mm wider on each side than the barrel of the pipe. When support of excavation is provided building paper shall be placed against that support before concreting to facilitate withdrawal of the support.

In the case of spigot and socket pipes with flexible joints the concrete protection at each joint shall be interrupted in a vertical plane at the edge of the socket by a strip of fibreboard or other material approved by the Engineer and of the following thickness:

Pipe nominal diameter [mm]	Fibreboard thickness [mm]
≤ 300	12
> 300 and ≤ 600	24
> 600 and ≤ 1100	36

Where two or more pipelines are laid in the same trench, the joints shall coincide at the points where the continuity of the concrete surround is broken at the joints in the pipeline with the longest pipes, and any intermediate joints in the other pipeline with shorter pipes shall be surrounded in concrete.

Pipework systems shall be complete and checked for correct position and alignment before and after being embedded in concrete.

Pipes in roads with heavy traffic have to be protected by appropriate drag plates.

Plastic pipes shall be wrapped with a layer of plastic sheeting before being surrounded by concrete.

E.2.7.6.14 Laying of Concrete Pipes

Laying of pipes shall generally be as specified in Section E.2.7.6, in accordance with the requirement as specified in EN 1610 and with the instruction of the manufacturer in the case of the factory made pipes, unless otherwise directed by the Engineer.

The pipe bedding material for concrete pipes shall be as follows:

- For pipes up to 1.200 mm internal diameter the granulation of the material shall be from 5 mm to 20 mm, all passing 20 mm and not more than 20 % passing 5 mm sieves;
- For pipes above 1.200 mm internal diameters the granulation of the material shall be from 5 mm to 37,5 mm all passing 37,5 mm, not more than 45 % passing 20 mm and not more than 20 % passing 5 mm sieves. The pipes shall be laid on the backfilled, graded and finished bedding of the trench and special joint holes shall be provided. Spigot and socket pipes shall normally be laid with the socket at the upper higher end.

The whole inside and outside area forming the joint of pipes and fittings shall be thoroughly cleaned before laying. Every precaution shall be made to prevent foreign material entering the pipes. During laying operation no debris, tools, cloth or other material shall be placed in the pipe.

Except where concrete protection is to be provided the Contractor shall not, at any stage in the laying of pipes support the pipes on anything else than granular material. Temporary packing of brickwork, stones etc., will not be permitted.

During the jointing, displacement of the rubber ring shall be prevented in the case of adopting the sliding method. The noose shall not be removed until the joint is made and the pipes sufficiently supported and after the approval of the Engineer.

E.2.7.6.15 Laying and Jointing of Ductile Iron Pipes

Laying of pipes shall generally be in accordance with the requirements of the applicable standard and with the instruction of the manufacturer.

The pipes shall be laid in straight lines both in horizontal and vertical planes. Changes of direction of less than 11,25° shall be obtained by deviating the pipes after jointing at one or more joints. The angle of deviation at each joint depends on the ND and has the following maximum values:

Nominal Diameter DN [mm]	Maximum Deviation
100 to 150	5°
200 to 300	4°
350 to 500	3°
600 to 700	2°
800 to 1100	1°30'

No deviation can be made at a locked joint.

The general jointing procedure may vary with the type of joint used, but the basic requirements are:

- Overall cleanliness;
- Correct positioning of the components;
- Correct centring of the spigot in the socket;
- Strict observance of the manufacturer's assembling instructions.

The Contractor shall be responsible for providing the necessary copies of these instructions.

The contractor has to make sure that the pipes and fittings will meet the requirements for the negative and positive pressure and a related calculation has to be provided. Where needed the pipe connections have to be fixed in longitudinal direction by using TYTON joints according to DIN 28603 or equivalent.

E.2.7.6.16 Laying of Steel Pipes

Transport, laying and measurement of steel pipes shall be in accordance with the rules outlined for DI pipes.

However, the specific requirements for the jointing and handling of steel pipes are summarised as follows:

- Steel pipes shall be joined together by electric butt-welding. Welding shall be in accordance with approved standards. The electrodes used shall be suitable for overhead welding and shall be subject to the Engineer's approval. Pipes shall be joined beside the trench;
- The Contractor's welders shall have passed welding tests as prescribed by the Engineer and no welder shall work on the pipes before passing the test and being approved by the Engineer in writing;
- After passing the prescribed pressure test, external coating of all joints shall be completed in accordance with the Engineer's instructions and to his satisfaction;
- After inspection of the joints the pipes shall be lowered into the trench.

E.2.7.6.17 Laying of HDPE Pipes

Pipes supplied in rolls shall be taken from the roll, straightened, cut to the required lengths, positioned and bedded in the trenches on the compacted or concrete bedding and jointed with the appropriate fittings.

Pipes supplied in bars shall be positioned and bedded in the trenches on the compacted or concrete bedding and joined as required.

E.2.7.6.18 Laying of GRP Pipes

Pipes shall be laid in the trench straight and without tension. The maximum allowed change of direction on the joint coupling shall be in accordance to the manufacturer's instructions and not more than 3°.

E.2.7.6.19 Laying of Galvanised Iron Pipes

If ordered by the Engineer, the installation of GI pipes, diameters ranging from ½" to 1", from behind the water meter to the consumer's house piping system shall be executed by the Contractor.

Piping shall include all fittings, connecting materials, supports, earthwork chiselling, mending and pressure tests for the complete installation of GI pipes in every respect.

E.2.7.7 Pipe Joints

E.2.7.7.1 General

The Contractor shall use only the proper jointing parts as specified and obtained from the suppliers of pipes or fittings. All joints shall be assembled and tightened in accordance with the manufacturer's instructions.

Unless specified otherwise joints having exposed mild steel components shall be cleaned and all loose rust shall be removed. The internal lining in a gap, which has been left for the joint to be made, shall be completed in accordance with the recommendations of approved supplier, unless specified otherwise. The external protection shall comprise bitumen applied to a thickness of not less than one millimetre on to the external surface of the joint, followed where appropriate by a spiral wrap of heavy duty glass fibre tape bonded with hot bitumen.

Solvent cement type joints shall not be used for pipe jointing.

E.2.7.7.2 Push-in Joints

Joint rings and gaskets shall be stored until needed in a cool place protected from direct sunlight.

The pipes shall be positioned and bedded in the trenches on the compacted and finished bedding and jointed in an approved manner using the proper lubricant, rubber rings and methods in strict accordance with the manufacturer's instructions.

Special care shall be taken to see that the axis of the pipe to be laid forms one straight line with the axis of the previously laid pipe. Spigot and socked ends shall be central with regard to each other.

The inside of the socket and the outside of the spigot end shall be thoroughly cleaned to remove oil, grit, excess coating, and other foreign matter. The circular rubber gasket shall be flexed inward and inserted in the gasket recess of the bell socket.

The following measures shall be taken for joints made with the "sliding method". A thin film of gasket lubricant shall be applied to either the inside surface of the gasket or the spigot end of the pipe, or both. The gasket lubricant shall be as supplied by the pipe manufacturer and approved by the Engineer. In no case shall an un-approved lubricant be used. The substance to be used needs to be approved by the manufacturer of the rubber rings.

For joints executed by "rolling" of the rubber ring the Contractor shall ensure that spigot and socked ends and the rubber ring are completely dry and clean before insertion of the joint. The positioning of the rubber ring shall be such that twisting is prevented while the circumferential stress is applied before each joint is made.

The spigot end of the pipe shall be entered into the socket with care to keep the joint from contacting the ground. The joint shall then be completed by forcing the plain end to the bottom of the socket with a forked tool, jack-type tool, by leverage with an iron bar against the opposite end of the pipe being installed or other device approved by the Engineer.

A wooden block or other suitable device shall be used to prevent any damage to the socket against which the bar is being pressed. No blocking will be allowed under the pipe, and it shall bear evenly along its entire length on the bedding material. Particular care shall be applied to ensure that the spigot end of the pipe does not damage or displace the rubber ring joint. Pipes that are not furnished with a witness mark shall be marked before assembly to assure that the spigot end is inserted to the full depth of the joint. Field cut lengths shall be filed or ground to the same dimension as the manufactured spigot end.

A penetration gauge shall be used to check each joint after assembly, to ensure that the rubber ring is properly seated. When it is desired to deflect push-on joint pipe in order to form a long radius curve, the amount of deflection shall be directed by the Engineer and the instructions of the manufacturer shall be observed. It is important that in making the joint, the pipes are maintained in a straight line and the deflection introduced after the joint has been assembled.

After completing the joint any protective or other coating shall be made good and any lining and joint protection completed as specified without delay.

The pipe shall be secured in place with approved backfill material (preferable concrete B 5-10 on fine sand) tamped around it, except at the joints. Pipes shall be laid in such a manner that the whole body of the pipe is in contact with the bedding. Precautions shall be taken to prevent dirt from entering the joint space. All joints shall remain uncovered until successful completion of the pressure test.

The Contractor shall supply all the materials, equipment and tools required for the proper jointing of the pipes at his own cost.

The finished pipeline shall run straight between the bends and curves and a uniform gradient shall be accurately maintained between changes of gradient as directed by the Engineer. All pipelines must be inspected and approved by the Engineer before they are tested and finally covered.

E.2.7.7.3 Mechanical Joints

To assemble the joint, the Contractor shall thoroughly clean the joint surfaces and rubber gasket with soapy water before inserting the spigot into the socket of the joint. Bolts shall be tightened alternately on opposite sides of the joint diameter and in rotation around the pipe. When properly assembled, the gland shall be equidistant from the socket face at all points.

All mechanical joints shall have their coating made good before assembly.

E.2.7.7.4 Flanged Joints

Flanged joints shall be properly aligned before any bolts are tightened. Gaskets shall be used at all flanged joints. Gaskets for flanged joints shall be of the inside-bolt-circle type. Slip-on flanges shall be double welded to the pipe with a full strength fillet weld joining the flange hub to the pipe, and a seal fillet weld inside the flange at the pipe end. Jointing compounds shall not be used when making flanged joints, except that to facilitate the making of vertical joints, gaskets may be secured temporarily to one flange face by a minimum quantity of clear rubber solution.

Flanged joint pipe shall be firmly and fully bolted with machined bolts provided by the manufacturer. Bolt threads shall be treated with graphite paste and the nuts shall be tightened gradually and evenly in diametrically opposite positions using only standard spanners of type approved by the Engineer. Nuts shall be secured against loosening by vibration.

E.2.7.7.5 Welded Joints

Welding of joints shall be carried out in accordance to Section E.3.3.3.5 for HDPE pipes and Section E.3.7.6 for steel pipes.

E.2.7.7.6 Thrust resisting Joints

The Contractor shall use fittings with thrust resisting joints where appropriate to prevent the main from pulling apart at certain pipe sections and where those sections are not anchored otherwise.

E.2.7.8 Trenchless Pipe Laying

This paragraph concerns the installation of water supply or sewer lines by horizontal directional drilling. Works shall include all materials, equipment, labour and work as required.

Horizontal directional drilling equipment shall comprise the following:

- Directional drilling rig of sufficient capacity to perform bore and pull-back operations;
- Drilling fluid mixing, delivery, and recovery system of suitable capacity;
- Automated magnetic guidance system with sufficient accuracy;
- Automated detected and warning system to locate other infrastructure ahead of bore;
- Tanker truck or other suitable mobile storage for handling of drilling fluid;
- Steel casings of various diameter, fit for purpose;
- Any other equipment required for horizontal directional drilling.

Any equipment shall be in good and safe operating condition with sufficient spares and consumables to ensure continuous operation.

Horizontal directional drilling shall be undertaken in 2 steps:

1. A pilot bore shall be driven with no deviations from the bore path;
2. Upon completion of the pilot hole the bore shall be reamed to ≥ 10 to 25 % of the outside diameter of the pipe to be installed.

Once reaming is completed, graded casing shall be pulled-in, giving sufficient support to avoid damage of the pipe.

Pull-back of the pipe shall be through wet insertion.

The Contractor shall maintain a thorough and neat boring log, subject to the Engineer's approval. Works shall be implemented in close coordination with the Employer and relevant authorities. Safety procedures have to be closely followed.

E.2.7.8.1 Construction Site Requirements

Excavation for entry, recovery pits, slurry sump pits, or any other excavation shall be carried out as specified in Section D.4.2. Sump areas are required to contain drilling fluids.

After completing installation of the product, the work site shall be restored. The work site shall be cleaned of all excess slurry left on the ground. Removal and final disposition of excess slurry or spoils as the product is introduced, shall be the responsibility of the boring contractor.

Excavated areas shall be restored. The cost of restoring damaged pavement, curb, sidewalk, driveways, lawns, storm drains, landscape, and other facilities is borne by the Contractor.

E.2.7.8.2 Quality Control

A representative of the Contractor must at all times have control over the execution of the works. The representative must have a thorough knowledge of the equipment and the procedures to be performed, and to be present at the construction site during installation.

The Engineer must be notified at least 48 hours in advance of starting work. The installation shall not begin until the Engineer is present at the construction site and agrees that proper preparations have been made.

E.2.7.8.3 Boring Path Report

The Contractor shall furnish a Bore Path Report to the Engineer within 14 days of the completion of each bore path. The completed As-Built-Plans shall be submitted to the Engineer within 30 calendar days. The report shall contain:

- a) Location of project;
- b) Name of person collecting data, including title, position, and company name;
- c) Investigation site location (contract plans station number or reference to a permanent structure within the project right of way);
- d) Identification of the detection method used;
- e) As-built placement drawings showing roadway plan and profile, cross section, boring location and subsurface conditions as defined in Bore Path Drawings below. Plan elevations shown shall be referenced to the given bench mark and to the used grid system and datum. These drawings shall be done to the same scale in black ink on white paper, of the same size and weight.

E.2.7.8.4 Boring Path Drawings

Boring Path Drawings shall be dimensionally correct copies of the contract plans. Notes shall be included on each drawing stating the final bore path diameter, facility diameter, drilling fluid composition, composition of any other materials used to fill the annular void between the bore path and the pipe. The drawings shall be produced as follows:

- a) The contract plan view shall show the centre-line location of each pipe installed to an accuracy within 3 cm at the ends and other points physically observed. They show the remainder of the horizontal alignment of the centre line of each pipe and note the accuracy with which the installation was monitored.
- b) As directed by the Engineer, either a profile drawing for each bore path, or a cross section of the roadway at a station specified by the Engineer, or a roadway centreline profile, shall be provided. They shall show the ground or pavement surface and the crown elevation of each facility installed, or installed and placed out of service, to an accuracy within 3 cm at the ends and other points physically observed. It shall show the remainder of the vertical alignment of the crown of each pipe and notes the accuracy with which the installation was monitored. On profile drawings for bore paths crossing the roadway the contract plans stationing of the crossing shall be shown.
- c) On the profile drawings for bore paths paralleling the roadway the contract plans stationing are also shown.
- a) If the profile drawing for the bore path is not made on a copy of one of the contract profile or cross section sheets, a 10 to 1 vertical exaggeration shall be used.

E.2.7.8.5 Directional Boring

The work specified in this Section documents the approved construction methods, procedures, and materials for Directional Boring, also commonly called Horizontal Directional Drilling (HDD).

Drilling Fluids & Reamer Hole Diameter The Contractor shall identify the source of fresh water for mixing the drilling mud. Approvals and permits are required for such sources as streams, rivers, ponds, or fire hydrants. Any water source other than potable water may require a pH test.

A mixture of bentonite clay or other approved slurry and potable water shall be used as the cutting and soil stabilisation fluid. The viscosity shall be varied to best fit the soil conditions encountered. Water shall be clean and fresh, with a minimum pH of 6.

No other chemicals or polymer surfactant is to be used in the drilling fluid without the written consent of the Engineer and after a determination is made that the chemicals to be added are not harmful or corrosive to the facility and are environmentally safe.

Monitoring of the drilling fluids such as the pumping rate, pressures, viscosity, and density is required during the pilot bore, back reaming, and pipe installation stages, to ensure adequate removal of soil cuttings and the stability of the borehole. Relief holes can be used as necessary to relieve excess pressure down hole. To minimise heaving during pullback, the pull back rate is determined in order to maximise the removal of soil cuttings without building excess down hole pressure. Excess drilling fluids shall be contained at entry and exit points until they are recycled or removed from the site. Entry and exit pits shall be of sufficient size to contain the expected return of drilling fluids and soil cuttings.

The Contractor shall ensure that all drilling fluids are disposed of or recycled in a manner acceptable to the appropriate local, state, or federal regulatory agencies. When drilling in suspected contaminated ground, the drilling fluid shall be tested for contamination and disposed of appropriately.

Any excess material shall be removed upon completion of the bore.

Restoration for damage to any transportation facility or non-transportation facility caused by heaving, settlement, escaping drilling fluid (fracout) or the directional drilling operation, is the responsibility of the Contractor. Any pavement heaving or settlement damage requires restoration / replacement of the pavement.

Testing When there is any indication a pipe has sustained damage and may leak, the work is to be stopped and the damage investigated. The Engineer may require a pressure test. The testing may consist of one of the following methods but shall always meet or exceed the testing requirements stated in Section E.4.

- a) Manufacturer's pressure testing recommendations for the type of pipe being installed shall be followed. The Engineer shall be notified and at his option be present during the test for review of the test results for compliance. The pressure test shall be performed within 24 hours. A copy of the test results shall be furnished to the Engineer. If the pipe is not in compliance with specifications, the Engineer may require it to be filled with flowable fill.
- b) Product carrier pipes installed without a casing must meet pressure requirements set by the Manufacturer. If the Manufacturer does not require pressure testing, the Engineer may require at least one test. A copy of the test results shall be furnished to the Engineer. If the pipe is not in compliance with specifications the Engineer may require it to be filled with flowable fill.
- c) The Engineer requires that conduit or pipe must meet or exceed soil tight joint requirements when leakage would not cause failure or adversely affect the integrity of the roadway pavement or shoulders.
- d) Where leakage could adversely affect pavement or shoulder integrity, a water tight joint is required.

Locating and Tracking The Contractor shall describe the method of locating and tracking the drill head during the pilot bore. The Engineer recognises walkover, wire line, and wire line with surface grid verification (i.e. True-Track), or any other system as approved by the Engineer, as the accepted methods of tracking directional bores. The locating and tracking system shall be capable of ensuring that the proposed installation is installed as intended. If an area of radio signal interference is expected to exceed 1,5 m, the Engineer may specify the use of a suitable tracking system.

The locating and tracking system shall provide information on:

- Clock and pitch information;
- Depth;
- Transmitter temperature;
- Battery status;
- Position (x, y);
- Azimuth, where direct overhead readings (walkover) are not possible (i.e. subaqueous or limited access;
- transportation facility. Before commencement of a directional drilling operation, proper calibration of the equipment (if required) shall be undertaken.

Alignment readings or plot points shall be taken and recorded every 1,5 m.

All facilities shall be installed in such a way that their location can be readily determined by electronic designation after installation. For non-conductive installations, this shall be accomplished by attachment of a continuous conductive material either externally, internally, or integrally with the product. Either a copper wire line or a coated conductive tape for this material may be used. Any break in the conductor must be connected by electrical clamp of brass or solder and coated with a rubber or plastic insulator to maintain the integrity of the connection from corrosion.

Equipment Requirements The Contractor shall ensure that appropriate equipment is provided to facilitate the installation. Equipment shall be matched to the size of pipe being installed. Installations must be approved by the Engineer. The Contractor ensures that the drill rod can meet the bend radius required for the proposed installation.

Multiple pipe or conduit installations shall not exceed the total outside pipe diameters stated above.

Obstructions If during installation an obstruction is encountered which prevents installation of the pipe in accordance with this specification, the pipe may be taken out of service and left in place at the discretion of the Engineer, and shall immediately be filled with flowable fill. A new installation procedure and revised plans must be submitted to and approved by the Engineer before work can resume. If a bore path is abandoned without installing a pipe, the drawings shall show the abandoned bore path along with the final bore path. The abandoned bore path shall be noted as "Abandoned Bore Path." They shall also show the location and length of the drill head and any drill stems not removed from the bore path. If conditions warrant removal of the materials installed in the abandoned bore path, as determined by the Engineer, during construction or in the future, the cost and responsibility shall be borne by the Contractor.

The type of material, horizontal and vertical location, top elevation and lowest elevation observed, diameter and material type of all utilities encountered and physically observed during the subsoil investigation shall be noted on the Contractor's approved shop drawings.

E.2.7.8.6 Jack and Bore / Micro-Tunnelling

The work specified in this Section documents the approved construction methods, procedures, and materials for Jack and Bore (J&B), also known as auger boring. Micro tunnelling (MT) is considered to be a hybrid of Jack and Bore for purposes of specifications.

Materials

Materials approved for installation shall be selected based on their suitability for the construction method as defined in the following table. After determining product suitability, individual material standards as contained in the subsequent table shall apply. Requirements on steel and RC pipe casings are specified hereinafter.

Type Pipe / Casing Installation Mode	Suitable Pipe / Casing
J&B Jacking	Steel pipe
MT Jacking	Ductile iron pipe, prestressed or reinforced concrete pipe, Steel pipe

Steel Pipe Casing The size of the steel casing shall be at least 15 cm larger than the largest outside diameter of the carrier pipe.

The casing pipe shall be straight seam pipe or seamless pipe. All steel pipes may be bare inside and out, with the manufacturers' recommended minimum nominal wall thicknesses to meet installation and loading requirements. Coatings to extend the service life may be permitted. All steel casing pipe shall be square cut and have dead-even lengths which are compatible with the J&B equipment.

All steel pipe casings and welds shall meet or exceed the thickness requirements to achieve the service life requirements. Steel pipe casing of insufficient length shall achieve the required length through fully welded joints. Joints shall be air-tight and continuous over the entire circumference of the pipe with a bead equal to or exceeding that required to meet the thickness criteria of the pipe wall. All welding shall be performed by a qualified welder.

Reinforced Concrete Pipe Casing In addition to the concrete pipe standards, the pipe shall comply with the following minimum requirements:

- a) 35 MPa concrete compressive strength;
- b) Strengthened wall as required by load calculations;
- c) Full circular inner and/or outer reinforcing cage;
- d) Multiple layers of steel reinforcing cages, wire splices, laps and spacers are permanently secured together by welding in place;
- e) Straight outside pipe wall with no bell modification;
- f) No elliptical reinforcing steel is allowed;
- g) Single cage reinforcement with a 3 cm minimum cover from the inside wall;
- h) Double cage reinforcement with a 3 cm minimum cover from each wall;
- i) Joints are gasket type;
- j) Additional joint reinforcement.

Upon installation, the Engineer may at his discretion require the contractor to perform concrete wiping or injection of the joints if it is believed the joints have not maintained their water tightness during the jacking operation. No additional payment will be made for this operation.

Ground Water Control When ground water level must be controlled, the system shall be compatible with the properties, characteristics, and behaviour of the soils as indicated by the soil investigation report.

Ground water may be controlled from sumps constructed inside the excavated areas (pits). When sump pumps are not sufficient to control the ground water, de-watering is required as specified in Section D.4.2.4.

Specific Micro-Tunnelling Requirements Continuous pressure shall be provided to the face of the excavation to balance groundwater and earth pressures. Shafts shall be of sufficient size to accommodate equipment, the pipe selected, and to allow for safe working practices. Entry and exit seals shall be provided at shaft walls to prevent inflows of groundwater, soil, slurry, and lubricants. Thrust blocks shall be designed to distribute loads in a

uniform manner so that any deflection of the thrust block is uniform and does not impart excessive loads on the shaft itself, or cause the jacking frame to become misaligned.

The Micro-Tunnelling boring machine (MTBM) shall meet the following minimum performance requirements:

- a) Capable of providing positive face support regardless of the MTBM type;
- b) Articulated to enable controlled sheeting in both the vertical and horizontal directions to a tolerance of plus or minus 2 cm from design alignment;
- c) All functions are controlled remotely from a surface control unit;
- d) Capable of controlling rotation. This is accomplished by a bi-directional drive on the cutter head or by using anti-roll fins or grippers;
- e) Capable of injecting lubricant around the exterior of the pipe being jacked;
- f) Capable of controlling heave and settlement to acceptable tolerances as indicated in the contract documents.

The main control system of the MTBM shall provide the following information to the operator as the minimum required for successful operation of the MTBM:

- Deviation of the MTBM from the required line and grade of the pipeline (normally by reference to a laser beam);
- Grade and roll of the MTBM;
- Jacking load;
- Torque and RPM of the cutter head;
- Instantaneous jacking rate and total distance jacked;
- Indication of steering direction. For slurry systems, the following shall be indicated:
 - The volume of slurry flow in both the supply and return side of the slurry loop;
 - The slurry bypass valve position.
- The pressure of the slurry in the slurry chamber. The jacking system shall have the capability of pushing the MTBM and pipe through the ground in a controlled manner and compatible with the anticipated jacking loads and pipe capacity. The jacking force applied to the pipe shall be monitored and not exceed the pipe manufacturer's recommendations.

The pipe lubrication system shall be functional at all times and sufficient to reduce jacking loads. Pipe lubrication systems shall include a mixing tank, holding tank and pumps to convey lubricant from the holding tank to application points at the rear of the MTBM. Sufficient fluids shall be maintained on site so as not to allow loss of lubrication.

Spoil removal capability and method shall be identified so as not to create a hindrance to other activities which may be necessary in the area.

Locating and Tracking For all installations, the Contractor shall submit sufficient information to establish his proposed strategy for providing:

- a) A positive indication of where the leading edge of the casing is located with respect to line and grade. This indication is provided with a water gauge (Dutch level), electronic transmitting and receiving devices, or other approved methods. The Contractor shall indicate the intervals for checking line and grade, and a record is maintained at the job site.
- b) Equipment of adequate size and capability to install the project. This includes the equipment manufacturer's information for all power equipment used in the installation.

- c) A means for controlling line and grade.
- d) A means for controlling overcut to a minimum, with the maximum limited to a 2 cm space around the circumference of the casing pipe.
- e) A means for centring the cutting head inside the borehole.
- f) A positive means for preventing the rear of the cutting head from advancing in front of the leading edge of the casing by more than 1/3 times the casing diameter in stable cohesive conditions not to exceed 20 cm. In unstable conditions, such as granular soil, loose or liquid materials, the cutting head is retracted into the casing a distance that permits a balance between pushing pressure, pipe advancement and soil conditions to assure no voiding takes place.
- g) Adequate casing lubrication with a bentonite slurry or other approved techniques.
- h) An adequate band around the leading edge of the casing to provide extra strength, which in loose, unstable materials when the cutting head has been retracted into the casing reduces skin friction as well as provides a method for the slurry lubricant to coat the outside of the casing.
- i) At least 6 m of full diameter auger at the leading end of the casing. Subsequent auger size may be reduced, but the reduced auger diameter must be at least 75 % of the full auger diameter.
- j) Water to be injected inside the casing to facilitate spoil removal. The point of injection is be no closer than 60 cm from the leading edge of the casing.

All the above options are required for major installations unless the Engineer has agreed in writing that they are not necessary. For both major and minor installations, the Contractor is responsible for submitting to the Engineer information indicating his proposed strategy for providing compatible materials and equipment.

All installations, facilities and equipment, shall be installed in such a way that their location can be readily determined by electronic designation after installation. For non-conductive installations this shall be accomplished by attachment of a continuous conductive material either externally, internally, or integrally with the product. Either a copper wire line or a coated conductive tape for this material may be used. Any break in the conductor must be connected by electrical clamp of brass or solder and coated with a rubber or plastic insulator to maintain the integrity of the connection from corrosion.

E.2.7.9 Pipes laid “Not in Trench”

Pipe laying items indicating that pipes are laid “not in trench”, include the pipe laying above ground (Section E.2.8). These items include following works with all materials, equipment, labour and work as required:

- All required pipe fixing systems;
- In case no near and/or adequate fixing point exists, the pipe laying items comprise all works required for the construction of the needed fixing points (e.g. reinforced concrete foundation block);
- All ancillaries including the required equipment for contact corrosion protection (between metal pipes and metal pipe fixing units;
- All “fittings” as required. The pipe fixing systems shall be submitted to the Engineer for approval. Depending on the pipe types, the fixing system type shall be designed according to the pipeline type (e.g. pressure or gravity pipe, diameter, etc.). As requested by the Engineer, the contractor shall provide structural design calculations of the fixing systems.

Metal systems shall be made corrosion resistant metal (e.g. stainless steel, galvanized steel, aluminium or epoxy coated steel).

When installing piped services, the following minimum clearances shall be provided:

- Walls: 300 mm
- Ceiling: 200 mm
- Floors: 200 mm
- cables and conduits: 150 mm No joint of any characteristics shall be made within walls, solid floors etc. or any other position where access for maintenance is difficult.

E.2.7.10 Marker posts

E.2.7.10.1 General

In order to leave permanent indication of the routes and depths of the pipelines and cables where they are below ground the Contractor shall provide and set up marker posts with indicator plate. Marker posts are not required for sanitary sewers with manholes.

The marker posts shall be set up as soon as practicable after trench excavations have been refilled but the Contractor shall provide any temporary marking required and shall be responsible for correct information being given on the indicator plates.

Marker posts shall be provided generally at 200 m spacing, at changes in direction of the main, adjacent to all valves and valve chambers, dead ends, and elsewhere as may be ordered by the Engineer. The depth to the top of the pipeline shall be indicated on all markers.

As directed by the Engineer the spacing of marker posts shall be varied where appropriate to avoid obstructing traffic or conflicting with other uses of the land.

Marker posts shall serve to mark DN and locations of valves, air venting and underground hydrants of mains. Locations shall be indicated by x, y offset originating from the location of the plate. Each unit shall consist of a plate and the letters and figures that shall be fixed to it. Letters and figures shall be 50 mm high and be of Latin character.

Plate, letters and figures shall be of weather-proof plastic or galvanised steel. The plate shall be fixed on a wall or at a galvanised steel or aluminium-alloy pipe of at least 40 mm. The pipe shall be fixed in the underground by concrete foundation.

The Contractor shall propose a proven system, according to the water supply company requirements and approved international Standards.

E.2.7.10.2 Marker posts for Water Networks

Markers for pipelines, valves and hydrants shall be prefabricated of concrete C 20/25 or aluminium with the following dimensions: 15 / 15 / 250 cm, with chamfered edges and placed in a concrete bed of 50 / 50 / 50 cm so that the marker protrudes 200 cm from ground level. The posts shall bear head of 25 x 35 cm having a recess of 10 mm and the size of 20 x 20 cm to receive the plate. At the edges of the recess, 4 dowel holes shall be provided.

Figures and letters on the plate shall show the following information on the valves: number of valve, DN and offsets; for hydrants: number of hydrant and offsets. Figures and letters shall be placed by the Contractor.

E.2.7.11 Marker Tapes

Marker tapes shall serve to mark location of pipes in the ground and to prevent unforeseen uncovering and damage to the pipe. Marker tapes shall be laid 300 mm above pipe crest to mark location of mains in the ground and allow detection by all standard and advanced detection methods using conductors. Tape shall satisfy the requirements of EN

12613 be of PE or equivalent and be fitted out with at least one stainless steel or copper conductor. Thickness shall be not less than 0,25 mm and width shall be at least 50 mm. The tape shall be supplied in coils of at least 100 m.

The marker tape shall have following colours and warning signs or equivalent along the top section of the pipe:

- Water supply: blue with warning signs “Caution Water Main below”;
- Sewer pipe: brown or orange with warning signs “Caution Sewer Pipe below”;
- Electrical cable or cable duct: red with warning signs “Caution Electric Cable below”;
- Gas pipe: yellow with warning signs “Caution Gas Pipe below”;
- Telecommunication cable or cable duct: green with warning signs “Caution Telecommunication Cable below”.

Plastic strips of light, bright colours and a width of 40 mm will be used to mark the pipes in the backfilled trenches. The plastic will be resistant to aging and of such qualities that the elongations at the breaking point will be at least 30% at a temperature of 200 C. Samples of the tape shall be submitted to the Engineer for his approval.

The provision and installation of these tapes are included in the duct pipe laying unit rates.

E.2.8 Erection of Pipework above Ground

Pipes shall be installed above ground where shown on the Contractor's approved shop drawings and/or as directed by the Engineer. Pipes for river crossings and bridge crossing and those exposed to sun radiation shall be of ductile cast iron as directed by the Engineer.

E.2.8.1 Preparation of Pipes

The Contractor shall be responsible for ensuring that the internal surface of all pipework is thoroughly cleaned before and during erection and before it is placed into commission.

Cleaning shall include the removal of all dirt, corrosion, scale and welding slag due to site welding. All small bore pipes shall be blown through with compressed air before connection is made to instruments and other equipment.

E.2.8.2 Installation of Pipes

Care shall be taken during the erection of pipework to ensure that no loads of any kind are transmitted through to the pump flanges or the flanges of any other equipment. Care shall also be taken that pipe flanges are accurately aligned to prevent distortion of flanges and/or pipework when bolting together. Bolts of flanged connections shall be tightened uniformly so that the gasket pressure is evenly distributed around the circumference.

E.2.8.3 Installation of Appurtenances

E.2.8.3.1 General Requirements

Valves, fitting, plugs, and caps shall be set and jointed to a pipe in the manner specified above for cleaning, laying and jointing of pipes. The Contractor shall furnish all components required for construction of valve chambers and access to buried valves, including cast iron covers, as shown on the Contractor's approved shop drawings. Each valve and equipment on pipeline shall be supported by a concrete base but not concreted into the base.

E.2.8.3.2 Valves

Isolation valves, if required, shall be installed according to the Contractor's approved shop drawings and/or directed by the Engineer. Special attention shall be drawn to clean and careful installation of valves. Any foreign matter resting in valve seats shall be removed in order not to obstruct the efficient operation of valves.

E.2.8.3.3 Bends and Fittings

Bends, tees and other fittings shall be installed according to the Contractor's approved shop drawings and/or as directed by the Engineer.

E.2.8.4 Support of Pipework and Valves

The Contractor shall furnish and install all pipe hangers, attachments, and supports, including structural steel work foundations, hangers, saddles, sliding, expansion pieces, fixing bolts, foundation bolts, fixing and anchor points as required according to needs. For this purposes Contractor shall provide adequate technical solutions approved by the Engineer. Temporary bracing and supports shall be provided to adequately support the pipe during its installation and care shall be taken in placing pipes to prevent damage to the pipe coating or to adjacent structures or equipment. All supporting means shall be in place and installed before temporary supports and bracings are removed.

The Contractor shall install sleeves, puddle pipes or wall castings for all pipes passing through masonry walls and concrete floors or walls and concrete inserts for hangers and supports as soon as formwork is erected and before concrete is placed. Before setting these items, the Contractor shall check all plans and figures which have a direct bearing on the pipe location and he shall be responsible for the proper location of the pipes during the construction of the structures.

All pipes shall be rigidly supported by approved hangers, inserts, or supports with adequate provisions for expansion and contraction. Pipes shall not be supported from other pipes or from stairs, ladders, or walkways unless specifically directed by the Engineer. Where pipes are installed on structural steel supports, the pipe shall be fixed to them in order to avoid pipe movement. All vertical pipes shall be supported at appropriate length intervals approved by the Engineer, pipe collars, clamps, brackets, or wall rests, and at all points necessary to ensure rigid construction. Valves, meters, strainers and other devices mounted in the pipework and its associated equipment shall be supported independently of the pipe to which they connect.

E.2.9 Passing through and Connection of Pipes to Concrete Walls

E.2.9.1 General Requirements

Where pipes pass through a concrete or brick wall or structure, a wall pipe sleeve of appropriate dimensions shall be installed. Collars and/or short pipe pieces shall be used as directed by the Engineer to absorb any differential displacement that may occur at the interface between natural ground and the structure.

E.2.9.2 Sewer Pipes

Unless rare exceptions, passing through or connection of sewer pipes to walls of sewer works shall be sustainably watertight. Therefore, following standard shall apply to these works.

In case of pressure pipes and flanged pipes, connecting to walls or passing through walls:

- Method 1: Pipe insert sleeve with central flange and flange connections, to be cast in concrete walls;
- Method 2: Core drilling of concrete wall and installation of a pipe sealing insert (press-seal). In case of gravity pipes or flanged pipes
- Method 2: Passing through walls with: a wall core drilling and installation of a pipe sealing insert (press-seal);
- Method 3: Connecting to walls with: a pipe connection socket (including rubber gasket) that shall be cast in concrete walls.

Methods described for passing through of water supply pipes (Section E.2.9.4) are not allowed for wastewater and sludge pipes.

E.2.9.3 Duct Pipes

For duct pipes, passing through and connection to walls shall be made with insert sleeves, to be cast in the concrete walls.

E.2.9.4 Water Supply Pipes

Whenever pipework passes through walls, the Contractor shall provide block-outs and install the pipes only after the structure has been completed and grout the pipes in secondary concrete after the pipes have been accurately positioned. Peripheral expansion joint shall be installed before concreting the block-out. Where axial thrust is to be transmitted, puddle flanges shall be grouted and reinforcement be placed in such manner that the thrusts will be safely transmitted into the structure.

In exceptional cases the Engineer may accept to incorporate the pipes into primary concrete provided that all pipe elements and appurtenances are completely wrapped into PE-sheets.

E.2.9.5 Preparation before Concreting

Before “concreting”, the pipe inserts or voids shall be adequately and firmly fixed in position in order to avoid movement or damage.

Individual pipes of complex pipe systems shall not be built into the concrete structures before accurate fitting of the whole system. Moreover, in such cases, the contractor shall foresee a minimum number of “pipe connection / passing through” to be built according to method 2 (core drilling and press -seal) as described in section E.2.9.2. Core drilling, which will per definition be implemented after wall construction, will allow for easy adjustment of their location basing on the location of the “pipe connection / passing through” existing in the freshly built wall.

E.2.9.6 Case of Brickwork Walls

For passing through and connection to existing or planned brickwork walls, no extra payment shall be made for the related works.

In case of existing walls, the Contractor shall drill a hole with an adequate drilling machine. The remaining spaces shall be grouted and the surfaces shall be reinstated.

In case of walls to be built, the contractor shall incorporate a short pipe length (maximum 50 cm) with pipe socket, during wall construction.

E.2.10 Contact Corrosion

Insulating flange sets shall be provided where shown and where necessary to prevent contact between dissimilar metals. Each insulating flange set shall consist of an insulating gasket, insulating sleeves and washers and a steel washer. Insulating sleeves and washers shall be one piece when flange bolt diameter is 40 mm or smaller and shall be made of acetal resin. For bolt diameters larger than 40 mm, insulating sleeves and washers shall be 2-piece and shall be made of polyethylene or phenolic insulating gaskets shall be full-face.

E.2.11 Manholes and Chambers

The manholes and valve chambers shall be either cast in-situ or pre-fabricated reinforced concrete or prefabricated thermoplastics.

E.2.11.1 Pre-cast and In-situ Concrete Manholes and Chambers

Dimensions of pre-cast concrete manholes and chamber shall be as required by local conditions and project documentation. The access opening shall have a clear circular opening of 600 mm circular or rectangular of 600 x 600 mm i.e. according to the dimensions defined in the project.

Cast iron covers with frames shall be installed for all manholes and chambers.

The Contractor will request a static budget for precast manholes from the manufacturer prior to procurement. The static calculation for precast concrete or reinforced concrete manholes should be in accordance with EN 1917 (reinforcement bars, concrete exposure classes, resistance, etc.). Pre-cast concrete windows are built using moulds.

E.2.11.2 Water Supply and pressurised Sewer Chambers

Reinforced concrete chambers for water supply and pressurised sewer shall be located as indicated on Drawings or directed by the Engineer. In-situ concrete chambers shall comply with the applicable specified requirements for Earth Works and Concrete Works. All external pipework before entering and after exiting a reinforced concrete chamber shall be fitted with flexible joints at a minimum distance of 300 mm from the external face of the chamber.

The following types of chambers shall be applicable for water supply and/or pressurised sewer:

- Gate valve chamber;
- Service valve chamber;
- Air valve chamber;
- Washout chamber;
- Water meter chamber in main lines;
- Chambers for other valves. The structures shall be built into the pipelines in accordance with the Contractor's approved shop drawings. Given dimensions on the Contractor's approved shop drawings shall be verified by the Contractor so as to suit the pipe installation and the prevailing conditions on Site.

Blinding of not less than 10 cm thickness and an offset of not less than 5 cm shall be provided for all in-situ cast chambers. Pre-cast chamber bases shall be laid in lean concrete of not less than 10 cm thickness.

The floor of the chambers shall have a minimum slope of 3 % towards a drain sump with a minimum size of 400 x 400 x 200 mm.

Two pairs of keys for use with each type of cover shall be handed over by the Contractor after completion of works at no extra cost.

All valve chambers shall be equipped with step irons as directed by the Engineer. All valve chambers shall have pump sumps installed as instructed by the Engineer.

E.2.11.3 Sewer Inspection Manholes and Chambers

E.2.11.3.1 General Construction Requirement

Manholes and valve chambers shall be located as directed by the Engineer. The Contractor shall construct chambers and manholes to the levels, dimensions and shapes as directed by the Engineer.

All manholes and inspection chambers shall be placed at all changes in direction, either horizontally and vertically, and connections to sewer lines. Exceptions are allowed if the bend is of small angle, at the chamber connections and if it does not prevent a video inspection. They must however be submitted for approval to the Engineer.

The construction of chamber and manholes shall comprise:

- According to the requirements of the manufacturer, for prefabricated chambers.
- Well compacted blinding layer, concrete C 12/15, thickness 10 cm; The width of the concrete base must be wider than the manhole for 300 mm on each side.
- Connections of the pipes to the bottom of the manhole will be made on the same way as the standard sealing ring for the sewer equipment.
- For manholes (i.e. allowing persons to enter), ladder or steps to be gradually distributed and compliant with Section E.2.11.6
- Frame and cover;
- The contractor shall protect the cover and cover frame until the final road or ground surface reinstatement works. The placing of the cover and cover frame shall be adjusted with the final reinstatement surrounding road or ground surface.

E.2.11.3.2 Reinforced Concrete Manholes and Chambers

Reinforce concrete manhole have to be prefabricated and compliant with EN 1917.

The contractor may propose alternatively the construction of insitu reinforced concrete chambers. The design shall be submitted for approval to the Engineer.

In-situ concrete manholes and chambers shall comply with the applicable specified requirements of the present general specifications for Earth Works and Concrete Works.

The construction of prefabricated and insitu concrete manholes shall comprise:

- a) well compacted blinding layer, concrete C 12/15, thickness 10 cm;
- b) bottom of manholes, in cast-in place, as shown on the Contractor's approved shop drawings. The Contractor may propose the construction of the bottom of the manholes in pre-cast concrete, being subject to the approval of the Engineer;
- c) tops of manhole frames (rings) and covers to the elevations as indicated on drawings, unless otherwise directed;
- d) building in and grouting of pipe ends (watertight construction), iron steps (at 300 mm centres) and drop fittings (encased in concrete C 20/25);
- e) benching to manholes (plain concrete C 30/37, compacted, well-formed and smooth trowelled);
- f) placing of cast iron, GRP or plastic manhole covers including frames.

The change between shaft ring and shaft cover shall be done with a shaft neck / shaft cone. A cover plate shall only be used in case of unsatisfying height of the shaft. The compensation of small level differences between shaft neck and shaft cover or shaft plate and shaft cover shall be made with level adjustment rings. Several rings may be used. The maximum height however is 125 mm.

Manhole inverts and benching in sewer pipes, drains and culverts shall be formed in concrete grade C 20/25 to the same gradient and diameter as the connected pipe works and with a smooth finish.

Inlet and outlet pipes shall be connected with channels at the bottom of the manhole. Channels shall be smooth with a size equal to the diameter of the inlet and outlet pipes. Changes in direction of flow shall be with smooth curves, as large as the size of the manhole permits. The bottom of the manholes shall have a minimum slope of 3 % towards the channels.

Inverts and junctions for pipes up to and including 400 mm diameter shall be formed of half-round, pre-formed channels, bends, tapers and specials. Inverts and junctions for pipes over 400 mm diameter shall be carefully formed in situ with 25 mm mortar shredding floated to the required shape.

The channel and the tread shall be protected against chemical attacks by the wastewater with appropriate coating.

E.2.11.3.3 Prefabricated Thermoplastic Inspection Chambers

The requirements for the prefabricated thermoplastic inspection chambers are summarized hereafter:

Item	DN400*	DN600	DN1000
Type	Inspection chamber	Inspection chamber	Manhole
Inner diameter	400 to 450mm	600mm	about 1000mm
Minimum pipe diameter	DN/OD110mm	DN/OD110mm**	
Maximum pipe diameter	DN/OD315mm	DN/OD400mm	DN/OD500mm
Material	UPVC or PP or HDPE		
Standards	EN 13598, EN 124, EN 681, EN 12256, EN 12061, EN 13101, EN 14982		
Bench of chamber base	bench starting at minimum at ½ pipe height bench slope of at least 33%		bench starting at minimum at ½ pipe height bench slope of about 5%
Pipe connections to chamber base	±7.5° pipe connection angle via special connection fitting Connection angles: 180°, 150°, 120°, 90° Up to 4 connections		
Access ladder or steps	No		Yes
Nominal stiffness of shaft riser	SN4		SN2
Top shaft end	Cylindrical adapter		Cone DN1000/600
Gaskets	All gaskets between chamber elements are included and made of wastewater resistant elastomer gaskets		

*Also applicable and equivalent to DN425 or DN450mm

** with pipe reducer

All chambers shall allow a video inspection of sewer via a crawler camera system. Exceptions shall be submitted for approval to the Engineer.

E.2.11.3.4 Connections to Chambers above Benches or to existing Chambers

These connections shall be made by using following method:

- Core drilling at the location required and for the diameter required by the connection saddle/insert.
- Use of pipe appropriate connection saddle/insert according to the type of sewer chamber material and diameter, to make the connection between the sewer pipe and the sewer chamber.

Prefabricated Thermoplastic

E.2.11.4 Water Tightness

Concrete Quality In case reinforced concrete manholes, coatings to seal the manholes are not allowed. These manholes shall always be made of watertight concrete.

Joints Between Chamber Elements Assembly of all manhole elements (base and rings) shall be made with the insertion of elastomer gaskets between each element (gaskets according EN).

In case of reinforced concrete manholes, the profile geometry at assembly surfaces shall be in accordance with EN standards and drawings.

Pipe Connections Pipe connections to chambers or manholes shall be in accordance with Section E.2.9.

Hydro-insulation

Hydro-insulation of the manholes and chambers bottom and walls shall be applied in wet soils where the groundwater level exceeds the bottom of the manhole or chamber. The top of the hydro-insulation shall not be less than 0,5 m above highest ground level.

E.2.11.5 Covers

Cast iron covers and frames shall comply with EN 124. They shall be manufactured from cast iron and be coated with an approved heavy duty abrasion resistant pitch epoxide to a minimum of 375 microns. The load class shall be selected in according with the expected loadings. If not otherwise specified, heavy duty covers and frames shall be installed in all roads, streets and highways of width exceeding 3 m.

All covers will be framed and tested at the manufacturer's factory. Covers and frames shall be similarly marked, clearly and permanently, in a place that will not be visible when fitted in positions. All sewer manholes and manhole covers shall be from an approved manufacturer and will have a clear opening as detailed, and will be made to prevent sand from entering. All manhole covers will be ventilated, except for sites with special requirements. All frames will be fastened to the manhole panel with a screw or anchor.

The basic layout of the installation of cast iron covers in the cross section of the road according to the types (load capacity) is given in the following figure:

Unless otherwise directed, cast iron covers shall have the following bearing capacity.

Class	Minimum required	Bearing capacity	Location of installation
(acc. to EN 124)	load class	[kN]	
1	A 15	15	Green areas and areas where only pedestrians and cyclists have access
2	B 125	125	Car parks and pedestrian areas where only occasional vehicular access is likely
3	C 250	250	Car parks, forecourts, industrial sites and areas with slow moving traffic
4	D 400	400	Areas where cars and lorries have access, including carriageways, hard shoulders and pedestrian areas

The above indicated bearing capacities may be amended to suit the actual site conditions.

The provision and installation of covers shall always include the provision of a compatible frame. The related costs are to be included in the cover rate (or chamber rate if the cover rate is also included in the chamber rate). In all cases, chamber frames and covers shall be constructed so as to permit adjustment should the elevation of the road change. All removed chamber frames and covers need to be returned to the related local authority.

Covers of concrete manholes and chambers located in the asphalt-concrete paved road or pavement areas shall be placed on the same level as the surface of the road (asphalt). Covers of manholes and chambers in green areas shall be at higher level than the ground level as follows:

- In built-up areas: 0,05 m;
- In non-built up areas: 0,20 m. Covers shall fit tightly on frames to avoid vibration under passing traffic. This must be demonstrated to the Engineer before the concerned road is open to traffic.

All sewer manhole covers shall be equipped with dirt pans.

Unless otherwise specified, all covers shall be provided with approved corrosion resistant locking mechanism and provisions for lifting. Holes provided in covers for lifting shall be appropriately shaped pockets and there shall be no projections above cover level.

All chamber covers supplied under this Contract shall be embossed with the words as agreed with the Engineer in advance of the Contractor manufacturing the covers.

E.2.11.6 Steps and Ladders

If not otherwise specified, steps in manholes and inspection chambers shall comply with the specifications of EN 1917 and be made of cast-iron with rubber coating or stainless steel with plastic coating, well covered against erosion and of 25 mm diameter, dimension 300 x 270 mm. Steps are placed evenly, at a maximum distance of 35 cm.

Safety Ladders According to standard EN 353-1, manholes with a depth greater than 5 m shall be provided with safety access ladders with guard rail, with design certification and CE marking, in accordance with EN 14396, made of 1.4307 (AISI 304 L) stainless steel, designed to attach an insertable entrance aid.

E.2.11.7 Lifting Keys

Lifting keys, tee keys and hooks for manholes and other chambers shall be black steel suitable for use with the covers supplied and shall be obtained from the cover Manufacturer. A set of lifting keys shall be supplied by the Contractor with each grade of covers.

E.2.11.8 Passing Through and Connections to Existing Chambers

For connections to existing reinforced concrete chambers shall the specification of section E.2.9 shall apply.

The Contractor is obliged to perform a preliminary geodetic survey of the manhole height and to make the necessary changes and adjustments to the level in order to make the connection to the existing manholes.

E.3. Material and equipment

E.3.1 General

All pipes, fittings and valves and all materials and other equipment shall conform to the relevant local or international norms and standards. The Contractor shall, if requested, forward to the Engineer certificates showing that the materials have been tested and comply with the requirements of these Specifications and the relevant standards.

Only those materials that meet the provisions of the Law on Construction Products and that are approved and accepted by the Engineer are procured and installed. Materials which are rejected shall immediately be removed from the Site at the cost of the Contractor.

E.3.2 Concrete Pipes

E.3.2.1 Standards

Main applicable standards are, but shall not be limited by the following:

- EN 1916 Concrete pipes and fittings, unreinforced, steel fibre and reinforced;
- EN 639 Common requirements for concrete pressure pipes including joints and fittings;
- EN 640 Reinforced concrete pressure pipes and distributed reinforcement concrete pressure pipes (non- cylinder type), including joints and fittings;

- EN 641 Reinforced concrete pressure pipes, cylinder type, including joints and fittings;
- EN 642 Pre-stressed concrete pressure pipes, cylinder and non-cylinder, including joints, fittings and specific requirements for pre-stressing steel for pipes;
- EN 1917 Concrete manholes and inspection chambers, unreinforced, steel fibre and reinforced;

E.3.2.2 General

Concrete pipes shall be used exclusively for buried gravity pipes within the fields of sewerage, rainwater drainage and waste water treatment works, but always above the groundwater level.

Concrete pipes should be made of sulphate resistant cement and show smooth inside and outside surfaces without honey-combed texture. The pipes, whether fresh or hardened, should not be treated, brushed or coated using water, cement grout, mortar or any other material. Pipes should not show cracks or penetrating holes. Pipes which do not comply with these requirements shall be rejected and removed from the site immediately.

The type of concrete used in the manufacture of the pipes shall be in accordance with Section D.7.3. No admixtures shall be added to the concrete without the written approval of the Engineer. Steel reinforcement for concrete pipes shall be in accordance with Section D.7.4.

Concrete pipes and fittings shall not be dispatched from the factory before 28 days have elapsed after manufacturing.

For the cutting of pipes, mechanical sawing machines shall be used such that the piece meets the requirements of the whole pipe. No hammering or chiselling will be allowed.

E.3.2.3 Classification

Concrete pipes used in the Works shall be classified under the following categories.

- a) Pipes with internal diameter ≤ 300 mm and below may be without reinforcement provided they meet the requirements of extra strength pipe class. They shall in accordance to EN 1916 (concrete pipes unreinforced).
- b) Pipes with internal diameter > 300 mm and above shall comply with EN 1916 (reinforced concrete pipes).
- c) Pre-stressed concrete pipes, shall comply with EN 642 (pre-stressed concrete pipes).

The pipes mentioned under a) shall have the following principal features:

- a self-centring socked joint with a performed gasket or rubber ring for insertion of the spigot. The pipes mentioned under b) shall have the following principal features:
 - a reinforcing cage (or cages) of steel bars, wire fabric or welded fabric.
 - a wall of dense concrete covering the reinforcement cage or cages.
- a self-centring socked joint with a performed gasket or rubber ring for insertion of the spigot. The pipes mentioned under c) shall have the following principal features:
 - Lined cylinder pipe (LCP): a concrete core cast inside a steel cylinder that serves as a watertight membrane. The cured concrete core is subsequently wire-wrapped and externally coated with a cement-rich mortar
 - Embedded cylinder pipe (ECP): a steel cylinder fully encased in a concrete core which is subsequently wire-wrapped and externally coated with a cement-rich mortar.
 - a self-centring socked joint with a performed gasket or rubber ring for insertion of the spigot.

E.3.2.4 Quality and Testing of Materials

The quality of the concrete for the pipes shall conform to the requirements as specified in EN 1916 and where applicable Section D.7.3. Generally, no reinforcement shall be used in the making of the pipes until the materials have been tested as specified. Certified copies of the test certificates shall be submitted to the Engineer.

Concrete for concrete pipes shall be manufactured from sulphate resisting Portland cement (CEM I) class CE I 42.5 in accordance to EN 197.

E.3.2.4.1 Unreinforced Concrete Pipes

Dimensions of not reinforced concrete pipes (300 mm internal diameter and less) shall conform to EN 1916.

The plane of the pipe ends except for shapes, shall be perpendicular to the longitudinal axis of the pipe. The interior surface shall be smooth and well finished. The pipes shall have the type of joints specified in Section E.3.2.5.

The pipe shall be free from fractures, cracks, laminations, or surface roughness.

Each pipe shall be marked clearly and legibly to show the manufacturer's name or trade mark, year and week number of production and minimum test bearing capacity (FN in kN/m)

E.3.2.4.2 Reinforced Concrete Pipes

Dimensions of reinforced concrete pipes (internal diameter greater than 300 mm) shall conform to EN 1916.

The circumferential steel reinforcement cage(s) shall be made of continuous or welded steel bars or wires of minimum cross sectional area of 1 % of the cross sectional area of concrete per metre length of pipe wound in a helical form, and individual bars shaped and butt or lap welded into cages, as approved by the Engineer. The circumferential bars or wires in the cage(s) shall be accurately spaced and shall be rigidly held by means of longitudinal bars or wires securely fixed to them in an approved manner. The axial pitch of the spiral reinforcement shall be less than 150 mm. Each cage shall be fabricated and rigidly held in such a manner that the reinforcement will remain in proper position during the casting of the pipe. The minimum cover to the reinforcing steel shall be 40 mm unless directed otherwise by the Engineer.

Concrete pipes shall be manufactured by either the centrifugal spun process or be vertically cast in a steel mould and shall be mechanically vibrated during the manufacturing.

E.3.2.4.3 Pre-stressed Concrete Pipes

Dimensions of pre-stressed concrete pipes shall conform to EN 642. Pre-stressed concrete pipes shall be of Lined cylinder pipe (LCP) or Embedded cylinder pipe (ECP) type in accordance to following specifications:

- LCP pipe shall have a concrete core cast inside a steel cylinder that serves as a watertight membrane. The cured concrete core shall be wire-wrapped and externally coated with a cement-rich mortar.
- ECP pipe shall have a steel cylinder fully encased in a concrete core that is subsequently wire-wrapped and externally coated with a cement-rich mortar.

The minimum cover to the steel cylinder inside shall be 40 mm, the minimum cover to the pre-stressing wires outside shall be 40 mm unless directed otherwise by the Engineer.

The spigot and bell joint rings shall be galvanised steel and in accordance to the following specifications.

Spigot and Bell Rings Outside Corrosion Protection A grout band shall be strapped to the outside of the completed joint so that it encompasses the external joint recess. A grout consisting of one part Portland cement, three parts sand, and sufficient water shall be mixed to produce a grout free of lumps and with a consistency of heavy cream. The grout shall be poured into the opening at the top of the grout band so that it completely fills the

external joint recess. The grout should be rodded or puddled to ensure complete filling of the joint recess. A stiffer mix can be used to trowel over the opening at the top of the grout band.

Spigot and Bell Rings Inside Corrosion Protection The interior, exposed surfaces of the steel joint rings shall be protected in one of the following ways:

- a) The interior joint recess shall be grouted using a stiff 1:3 Portland cement/sand mortar.
- b) A butyl rubber mastic joint filler shall be applied to the spigot end or bell socket prior to joining the pipe such that the mastic squeezes out and fills the interior joint recess.

E.3.2.5 Joints

E.3.2.5.1 Type of Joints

Unless otherwise specified, the joints for concrete pipes shall be of the spigot and socket type, sealed with continuous rubber ring gaskets. Joints shall be carried out in accordance with the requirements as described in the relevant standard and instructions of the manufacturer in the case of factory made pipes.

At changes in direction (bends) or nominal diameter (reducers) and when branching (tees) is constructed or at pipeline ends (blank flanges) joints shall provide restraint if the pipe is not secured according to Section E.2.7.6.10.

E.3.2.5.2 Sealing of Joints

The joints between the pipes shall be sealed with sealing rings made of styrene butadiene rubber. The sealing rings shall be stored in well covered areas and different types and/or dimensions shall be kept separate. Lists of deliveries shall be supplied and shall be handed over to the Engineer. The material shall be applied according to the recommendations of the manufacturer and the pipe joints must be of such quality that a leak-proof connection is guaranteed.

Joint lubricants for sliding joints shall have no deleterious effects on either the joint rings or pipes and shall be unaffected by the liquid to be conveyed in the pipes.

E.3.2.6 Inspection and Testing of Concrete Pipes

Inspection of concrete pipes will be made at the place of manufacture as may be deemed necessary by the Engineer or on delivery at the construction site. Pipes will be rejected as unsuitable for the Works for any of the following reasons:

- A piece of any size broken out of the pipe;
- Defects that indicate imperfect mixing or moulding of the concrete;
- Any crack extending through the wall of the pipe and having a longitudinal or transverse length greater than the wall thickness of the pipe;
- Any shattering or flaking of concrete;
- Any concrete deficiency on the inner surface of the pipe deeper than 10 mm of any area or on the outer surface of the pipe deeper than 10 mm of an area greater than 100 cm². The deficiencies in wall thickness permitted herein do not apply to gasket contact surfaces in gasket jointed pipe. Dimensions and tolerances of such contact surfaces shall be submitted for approval;
- A variation of more than 1 % from the true circle of the specified pipe internal diameter;
- Rock pockets and water pockets in any pipe;
- Exposure of any reinforcement or insufficient cover to reinforcement;
- Surface defects indicating honey-comb or open texture;
- Separation or "blisters";

- Any continuous crack having surface width of 0,25 mm or more and extending for a length of 300 mm or more, regardless of depth or position in the wall of the pipe;
- The pipe fails the strength test.

E.3.2.7 Repair of Pipe Imperfections

For pipes that are not rejected according to Section E.3.2.6 the following repair methods for small imperfection shall be applied:

E.3.2.7.1 Preparation of Surfaces to be repaired

Unsound or imperfect concrete shall be removed by careful chipping. Edges where concrete has been chipped out shall be scraped and square with the surface, leaving no feather edges. The chipped area shall be washed with water to remove all loose material and concrete dust.

Surfaces within the trimmed areas shall be kept wet for several hours, preferably overnight before the repair is made. All surfaces in areas to be repaired shall be damp, but not wet, when the material is applied.

E.3.2.7.2 Placement of Repair Mortar

The mortar used for repair shall in generally comply with the specification set forth in Section D.7.5.10.2 and contain an expanding additive.

Workmanship of repair shall be according to Section D.7.5.11.2.

E.3.3 Thermoplastic Pipes

E.3.3.1 Standards

The Contractor shall carry out the works described in accordance with the appropriate standards or equivalent local or international standards. The main standards are, but shall not be limited by the following.

- EN 13476 Plastics piping systems for non-pressure underground drainage and sewerage -Structured-wall piping systems of unplasticized poly(vinyl chloride) (PVC-U), polypropylene (PP) and polyethylene (PE);
- ISO 13267 Thermoplastics piping systems for non-pressure underground drainage and sewerage - Thermoplastics inspection chamber and manhole bases — Test methods for buckling resistance;
- ISO 13266 Thermoplastics piping systems for non-pressure underground drainage and sewerage - Thermoplastics shafts or risers for inspection chambers and manholes — Determination of resistance against surface and traffic loading;
- ISO 13260 Thermoplastics piping systems for non-pressure underground drainage and sewerage - Test method for resistance to combined temperature cycling and external loading;
- ISO 9969 Thermoplastics pipes. Determination of ring stiffness.
- ISO 21138-1 Plastics piping systems for non-pressure underground drainage and sewerage — Structured-wall piping systems of unplasticized poly(vinyl chloride) (PVC-U), polypropylene (PP) and polyethylene (PE) — Part 1: Material specification and performance criteria for pipes, fittings and systems;
- ISO 21138-2 Plastics piping systems for non-pressure underground drainage and sewerage — Structured-wall piping systems of unplasticized poly(vinyl chloride) (PVC-U), polypropylene (PP) and polyethylene (PE) — Part 2: Pipes and fittings with smooth external surface, Type A;

- ISO 21138-3 Plastics piping systems for non-pressure underground drainage and sewerage — Structured-wall piping systems of unplasticized poly(vinyl chloride) (PVC-U), polypropylene (PP) and polyethylene (PE) — Part 3: Pipes and fittings with non-smooth external surface, Type B;
- ISO 13262 Thermoplastics piping systems for non-pressure underground drainage and sewerage — Thermoplastics spirally-formed structured-wall pipes — Determination of the tensile strength of a seam;
- ISO 23711 Elastomeric seals — Requirements for materials for pipe joint seals used in water and drainage applications — Thermoplastic elastomers;
- EN 13598 Plastics piping systems for non-pressure underground drainage and sewerage - Unplasticized poly(vinyl chloride) (PVC-U), polypropylene (PP) and polyethylene (PE);
- EN ISO 12162 Thermoplastics materials for pipes and fittings for pressure applications - Classification, designation and design coefficient;
- ISO 161 Thermoplastics pipes for the conveyance of fluids - Nominal outside diameters and nominal pressures

E.3.3.2 Unplasticised Polyvinylchloride (PVC-U) Pipes and Fittings

E.3.3.2.1 Standards

The Contractor shall carry out the works described in accordance with the appropriate standards or equivalent local or international standards. The main standards are, but shall not be limited by the following.

- ISO 16422 Pipes and joints made of oriented unplasticised polyvinyl chloride (PVC-U) for the conveyance of water under pressure — Specifications;
- ISO 4435 Plastics piping systems for non-pressure underground drainage and sewerage — Unplasticised poly(vinyl chloride) (PVC-U);
- EN 1401 Plastics piping systems for non-pressure underground drainage and sewerage -Unplasticised poly(vinyl chloride) (PVC-U);
- EN ISO 1452 Plastics piping systems for water supply and for buried and above- ground drainage and sewerage under pressure - Unplasticised poly(vinyl chloride) (PVC-U);
- EN 1453 Plastics piping systems with structured-wall pipes for soil and waste discharge (low and high temperature) inside buildings - Unplasticised poly(vinyl chloride) (PVC-U);
- EN 1329 Plastics piping systems for soil and waste discharge (low and high temperature) within the building structure - Unplasticised poly(vinyl chloride) (PVC-U);
- EN 12200 Plastics rainwater piping systems for above ground external use - Unplasticised poly(vinyl chloride) (PVC-U);
- EN 1453 Plastics piping systems with structured-wall pipes for soil and waste discharge (low and high temperature) inside buildings - Unplasticised poly(vinyl chloride) (PVC-U);
- EN 1566 Plastics piping systems for soil and waste discharge (low and high temperature) within the building structure - Chlorinated poly(vinyl chloride) (PVC-C);
- EN ISO 15877 Plastics piping systems for hot and cold water installations - Chlorinated poly(vinyl chloride) (PVC- C);

E.3.3.2.2 Pipes, Fittings and Accessories - General

The Contractor shall advise the manufacturer of the climatic and transporting conditions at the site of the Works and shall seek his advice on the storage of PVC materials on site. Subject to the Engineer's approval this advice shall be followed at all times.

PVC granulate shall be virgin and comply with approved international health standards. PVC pipes shall be capable of withstanding ultraviolet degradation. A rodent inhibitor shall be incorporated in the material of the pipe. The Contractor shall provide such certificate for each 5000 m supplied from an institution appointed by the Engineer.

Except in the case of flanged joints and where otherwise specified or approved by the Engineer pipe joints shall be of the spigot and socket type, sealed with a flexible rubber ring or gasket to the approval of the Engineer and shall withstand the various tests specified in the applicable standards. Splicing joints are not allowed.

For pipes with a nominal bore of 600 mm or less, the joints shall be capable of withstanding a deflection of not less than 1,5 degrees in any direction and for pipes with a nominal bore of more than 600 mm 0,5 degrees in any direction.

All pipes shall be capable of withstanding a "draw" of 13 mm over and above the initial jointing allowance. The initial jointing allowance is the gap measured parallel to the centre line of the pipeline and shall not be less than 6 mm or more than 13 mm or as otherwise recommended by the pipe manufacturer and approved by the Engineer. Pipes and fittings shall be indelibly marked prior to laying to indicate the correct initial jointing allowance.

All PVC- U pipes shall have the following minimum required marking: Standard Number; Manufacturer's Name and/or Trade Mark; Material; Nominal Outside Diameter; Nominal Pressure PN; Manufacturer's Information (production period, year and name of the production site); Number of the extrusion line (if not included in manufacturer's information). Fittings shall have the following required minimum marking: Standard Number; Manufacturer's Name and/or Trade Mark; Nominal Diameter; Material; Nominal Pressure PN; Manufacturer's Information (production period, year and name of the production site).

Flanges shall have the following minimum required marking: Standard Number; Manufacturer's Name and/or Trade Mark; Nominal Size DN of Flange; Material; Nominal Pressure PN of Flange; Manufacturer's Information (production period, year and name of the production site).

Sealing rings will be procured together with pipes from the same manufacturer. The pipes will be procured in a straight length not exceeding 6 m. The ends of the pipes will be adequately protected from damage during assembly and transport.

The Contractor should keep in mind that rigid PVC pipes and equipment, as well as all other plastic pipes, are affected by heat so that the firmness of their material is reduced. Therefore, the Contractor should take all precautions to avoid exposing pipes and equipment to high temperatures, especially direct sunlight. When handling, transporting, storing and installing sewer pipes and equipment, they should be protected from direct sunlight. They should be stored in a sheltered, well-ventilated pile so that no part of the material is exposed to sunlight. Storage of sewage pipes and equipment under the rough hemp cloth, which is placed directly over the material, will not be allowed. During installation, the pipes will be backfilled about 300 mm above the top of the pipe immediately after installation. The joints, which will be exposed during the pressure test, shall be shielded with a hemp cloth placed at least 0.50 m above the pipe until the final backfilling begins. All pipes that, in the opinion of the Engineer, are damaged by the sun or heat shall be replaced with undamaged material, at the expense of the Contractor. The Contractor shall include all costs incurred, in strict compliance with the conditions set out above, in its prices for sewage pipes and equipment. Pipes and fittings which conform to EN Standards, and also conform to other standard(s) may be marked additionally with the number(s) of the other standard(s), together with the minimum required marking in accordance with the other standard(s).

E.3.3.2.3 Pipes, Fittings and Accessories for Pressurised Systems

All pipes, fittings and accessories shall be fabricated and supplied according to EN ISO 1452-2 (pipes) and EN ISO 1452-3 (fittings).

The pipe material to be used shall conform to EN ISO 1452-1 and to the requirements given in chapter 4.2 and 4.3 of EN ISO 1452-2.

Any deviation from these standards shall be inadmissible and shall lead to rejection of the material.

Pipes shall be at least of PN 10 SDR 21; the pipes and fittings shall be jointed by flexible push-fit collar type with rubber gaskets. Use of glue shall not be permitted.

The fitting material to be used shall conform to EN ISO 1452-1 and to the requirements given in chapter 4.2 of EN ISO 1452-3.

Fittings with flanges shall be of ductile iron, PVC or epoxy-coated.

E.3.3.2.4 Gravity Pipes

If there are no other factors which can influence the selection of gravity pipe class, pipes with ring stiffness 8 kN/m² (SN 8) shall be used.

E.3.3.3 Polyethylene (PEHD) and Polypropylene (PP) Pipes and Fittings

E.3.3.3.1 Standards

The Contractor shall carry out the works described in accordance with the appropriate standards or equivalent local or international standards. The main standards are, but shall not be limited by the following.

- ISO 4427-1 Plastics piping systems for water supply and for drainage and sewerage under pressure - Polyethylene (PE) - Part 1: General;
- ISO 4427-2 Plastics piping systems for water supply, and for drainage and sewerage under pressure - Polyethylene (PE) - Part 2: Pipes;
- ISO 4427-3 Plastics piping systems for water supply, and for drainage and sewerage under pressure Polyethylene (PE) - Part 3: Fittings
- ISO 8772 Plastics piping systems for non-pressure underground drainage and sewerage Polyethylene (PE);
- EN 12201 Plastics piping systems for water supply, and for drainage and sewerage under pressure - Polyethylene (PE);
- EN 12666 Plastics piping systems for non-pressure underground drainage and sewerage - Polyethylene (PE);
- EN 1519 Plastics piping systems for soil and waste discharge (low and high temperature) within the building structure - Polyethylene (PE);
- EN ISO 1587 Plastics piping systems for hot and cold water installations – Crosslinked polyethylene (PE-X);
- EN 1555 Plastics piping systems for the supply of gaseous fuels - Polyethylene (PE);
- DIN 8074 Polyethylene (PE) - Pipes PE 80, PE 100 – Dimensions ;
- DIN 8075 Polyethylene (PE) pipes - PE 80, PE 100 - General quality requirements, testing;
- ISO 8773 Plastics piping systems for non-pressure underground drainage and sewerage - Polypropylene (PP);
- EN 1852 Plastics piping systems for non-pressure underground drainage and sewerage - Polypropylene (PP);
- EN 10284 Malleable cast iron fittings with compression ends for polyethylene (PE) piping systems.

E.3.3.3.2 Pressure Pipes

HDPE (high density polyethylene) pipes shall comply with ISO 4427 and/or EN 12201 or equivalent standard. Principal and local mains shall be at least of SDR 17 (standard dimension ratio), PN 10. Service pipes shall be of SDR 11, PN 16.

The pipes and fittings shall be jointed in accordance with the diameters as set forth hereinafter.

PE granulate shall be PE 100 quality, be virgin and comply with ISO 4427 and/or EN 12201. In accordance with ISO 12162 the PE 100 material shall have a Minimum Required Strength (MRS) value of 10 MPa. The Contractor shall provide such certificate for each 5000 m supplied from an institution appointed by the Engineer.

Any deviation from these prescriptions shall be inadmissible and shall lead to rejection of the material. The pipe shall be coiled such that localised deformation, e.g. that buckling and kinking, is prevented. The minimum internal diameter of the coil shall not be less than 18 x nominal outside diameter. The ends of the pipe shall be plugged or covered.

If not otherwise specified, pipes outside diameter up to OD 125 shall be delivered in coils, the larger will be delivered in parts of 12 m.

The pipes must be stored in such a way that they are protected from exposure to direct sunlight. If covered with tarpaulins, the pipes and fittings shall be well ventilated to prevent any accumulation of heat and resultant deformation. Transparent sheeting or tarpaulins are not suitable for covering the pipes. The storage location should be flat and support the pipes over their entire length. The pipes must not be stored on stones or objects with sharp edges. Gaskets shall be always stored in a cool place protected from direct sunlight. Pipes should not be stacked to a height exceed 1 m. The pipes must be secured at the side to prevent them from rolling away. Contact with harmful media must be avoided. Coils should be stored in a horizontal and not on top each other. The pipes and pipeline parts shall be stored in such a way that they do not get dirty inside. Protection caps shall not be removed prior installation.

The minimum required marking for HDPE pipes shall conform to Standard Number; Manufacturer's Identification; Nominal diameter; SDR or k Series; Material and Designation; Pressure Rating in Bars; Production Period (date or code).

The metric system shall be used for flange connections. The following table shows the dimensions of HDPE pipes, SDR 17 and the corresponding nominal diameter (DN) of flanges:

Nominal Diameter	HDPE Pipe
DN1) [mm]	Outer Diameter OD [mm]
50	63
80	90
100	110
150	(160)
150	180
200	225
250	280
300	355
400	450

- 1) Nominal diameter according to EN 805 and EN 1092 for flanges

E.3.3.3.3 Pressure Pipes Joints

Pipes of diameters equal or less than OD 180 shall be joined with electro-fusion (EF) couplers of PE-HD. If approved by the Engineer, small diameter pipes (OD < 63 mm), pipes within structures and pipes connecting to metal fittings shall be jointed using mechanical jointing techniques, such as compression, flanged joints or push-fit joints. Pipes of diameters equivalent or larger than OD 180 shall be joined by butt fusion.

Fittings for diameters equal or less than DN 180 including service tee set flats shall be either of electro fusion type or compression type, all made of HDPE. Fittings for larger diameters shall be of butt fusion type.

Following rules shall apply for jointing of HDPE pipes with pipes of other material or valves:

- for joints between two HDPE pipe sections ($OD \geq 63$ mm) only electro-fusion couplings or butt fusion shall be used;
- for joints to ductile iron / steel pipes (spigot): very large coupling tolerance coupling shall be used;
- for joints between HDPE pipe and flanged valves: flanged spigot piece shall be used;
- for joints between HDPE pipe and other valves: valves EURO 20 Type 26 (or similar) shall be used.

The Contractor shall make his choice of either electro fusion or compression fittings and maintain the same type throughout the works. In case electro-fusion welded joints in high-density polyethylene pipes are foreseen, they shall be made only between pipes having the same physical characteristics. Joints between pipes from different manufacturers shall only be made with the specific approval of the Engineer and incorporate a flexible joint seal.

Flanges shall be made of hot-dip galvanised steel. The galvanisation shall be by hot-dip process according to ISO 20081 and/or EN 1179.

E.3.3.3.4 Pressure Pipes Fittings

All fittings shall be made according to ISO 4427 and/or EN 12201. Electro fusion adapter HDPE – galvanised steel pipes (thread female transition fitting) SDR 11 / S 5 shall be used for service pipes.

All fittings shall be permanently and legibly marked in such a way that the marking does not initiate cracks or other types of failure. The minimum required marking for fittings shall conform to Standard Number; Manufacturer's Name or Trade Mark; Nominal Diameter and Pipe Series / SDR; Manufacturer's Information; SDR Fusion Range; Material and Designation.

E.3.3.3.5 Pressure Pipes Butt Welding

PE HD pipes and fittings of diameter equivalent or bigger than DN 180 shall be jointed by heating-element butt welding. Heat fusion welding, extrusion welding and socket welding shall not be accepted.

The Contractor shall provide all necessary personnel, equipment and materials.

The Contractor shall supervise the site, the welders and their work during the entire working period. For this purpose, the Contractor shall use a qualified and certified welding specialist. Welding certificates shall be submitted to the Engineer.

Only skilled welders and welding operators who can document qualifications relevant for pipeline welding will be accepted by the Engineer. Prior to the performance of any production welding operators shall qualify for the relevant welding procedures according to DVGW W 330 or equivalent.

Surfaces to be welded have to be sufficiently clean, to avoid deterioration of weld quality by any dirt, oil, grease or other contamination.

Each pipe or component shall be visually inspected to ensure that it has not sustained any visually determinable damage. Disposition of damaged items shall be resolved in consultation with the Engineer.

Welding shall be suspended by the Contractor when prevailing weather conditions will impair the quality of the work, e.g. rain or thunderstorms.

Vibration inducing operations carried out in the vicinity of welding machine are prohibited during welding operations.

Welding shall be carried out only by using welding butt machines capable to weld all pipes from PN 2,5 to PN 40 according to the pipe material and having following characteristics:

- electro-hydraulic control of the pressure;

- automatic pipe cut;
- self-aligning frame;
- computer control of all welding steps after the facing operation, until the end of the welding cycle, providing easy set-up of the relevant welding data, in particular welding temperature. At the end of the cycle, a printer shall give the results of the weld with all necessary data according to international standard specifications. After welding, the joint shall be checked visually. In case of any of the following imperfections, the pipe ends shall be cut and welded again:
 - different high welding beads on pipe end;
 - welding beads too narrow and too tall;
 - welding beads too small;
 - crack on the centre of welding beads;
 - offset too high (10 % of pipes wall thickness is tolerated).

E.3.3.3.6 Gravity Pipes

If there are no other factors which can influence the selection of gravity pipe class, pipes with ring stiffness 8 kN/m² shall be used.

Extruded corrugated high density polyethylene (HDPE) pipes are used for sewer drainage pipes in accordance with EN 13476, will be procured from the approved manufacturer as well as all technical details related to sewage pipes and equipment to be used. The circumferential stiffness of the pipe is 8,0 kN / m² (SN 8) which is in accordance with EN 9969 (ISO 9969).

The ends of the pipes will be adequately protected from damage during transport and storage. When handling, transporting, storing and installing pipes and pipe equipment, they should be protected from direct sunlight. They should be stored in a sheltered, well-ventilated pile so that no part of the material is exposed to sunlight.

During installation, the pipes are placed on a previously made sand bed or small size gravel bed avoiding sharp edges and that the rib top rests on the excavation ground. The pipe is backfilled with the same material in a layer of 300 mm above the top of the pipe immediately after installation with manual compaction of the layer. All work during the laying of the pipe shall be performed by qualified workers in accordance with the applicable standards and the manufacturer's instructions

The joints, which shall be exposed during the pressure test, shall be shielded with a canvas placed at least 0.50 m above the pipe until the final backfilling begins. The installation and testing of the system should be in accordance with EN 1610. All pipes that the Site Engineer considers to be damaged by the sun or heat shall be replaced at the expense of the Contractor.

Extruded corrugated pipes are mounted using a socket and a flat part at the end. No fittings are required to mount the flat part of the pipe. The seals are placed in a gutter between the two circular reinforcements. HDPE pipes should have a smooth specially treated inner side in a lighter color. Only circular corrugated pipes will be used, spiral corrugated pipes will not be used.

Following the above mentioned requirements, the Contractor will include all costs incurred in the procurement, transport, installation, backfilling and pressure testing, strictly following the requirements mentioned above in its prices for sewage pipes and equipment.

E.3.4 Glass Fibre Reinforced Plastic (GRP) Pipes and Fittings

The Contractor shall carry out the works described in accordance with the appropriate standards or equivalent local or international standards. The main standards are, but shall not be limited by the following.

- ISO 16611 Plastics piping systems for drainage and sewerage without pressure — Non-circular pipes and joints made of glass-reinforced thermosetting plastics (GRP) based on unsaturated polyester resins (UP) — Dimensions, requirements and tests;
- EN 14364 Plastics piping systems for drainage and sewerage with or without pressure - Glass-reinforced thermosetting plastics (GRP) based on unsaturated polyester resin (UP) - Specifications for pipes, fittings and joints,
- EN 1796 Plastics piping systems for water supply with or without pressure - Glass-reinforced thermosetting plastics (GRP) based on unsaturated polyester resin (UP);
- EN 1115 Plastics piping systems for underground drainage and sewerage under pressure - Glass-reinforced thermosetting plastics (GRP) based on unsaturated polyester resin (UP);
- EN 705 Plastics piping systems - Glass-reinforced thermosetting plastics (GRP) pipes and fittings - Methods for regression analyses and their use;
- ISO 10467 Plastics piping systems for pressure and non-pressure drainage and sewerage - Glass-reinforced thermosetting plastics (GRP) systems based on unsaturated polyester (UP) resin;
- ISO 10639 Plastics piping systems for pressure and non-pressure water supply - Glass-reinforced thermosetting plastics (GRP) systems based on unsaturated polyester (UP) resin;
- CEN/TS 14578 Plastics piping systems for water supply or drainage and sewerage - Glass-reinforced thermosetting plastics (GRP) based on unsaturated polyester resin (UP) - Recommended practice for installation;
- CEN/TS 14807 Plastics piping systems - Glass-reinforced thermosetting plastics (GRP) based on unsaturated polyester resin (UP) - Guidance for the structural analysis of buried GRP-UP pipelines;
- ISO/TS 10465 Underground installation of flexible glass-reinforced pipes based on unsaturated polyester resin (GRP-UP);
- DIN 16868 Glass fibre reinforced unsaturated polyester resin (UP-GF) pipes;
- DIN 16869 Centrifugally cast filled glass fibre reinforced unsaturated polyester resin (UP-GF) pipes;
- DIN 16870 Wound glass fibre reinforced epoxy resin pipes; dimensions;

Glass-reinforced plastic pipes and fittings shall be supplied from an approved manufacturer. They shall be filament wound or centrifugal cast on automated machinery, capable of producing a product of consistent quality, maintaining a close tolerance on the designed locations and proportions of resin, glass and sand filler within the pipe wall, and minimizing trapped air. All raw material constituents shall be metered during manufacture.

The resin used in the main body of the pipe wall shall be of the isophthalic polyester type. The pipes shall have an internal, resin rich primary barrier of not less than 1,0 mm thickness. The resin used in the inner barrier layer shall be of the isophthalic polyester type, or if required for high corrosion applications, of vinyl ester or bisphenol A.

The external surfaces of the pipes shall also have a resin rich layer, but of isophthalic polyester resin unless otherwise required for particularly aggressive ground conditions. The pipes shall be capable of being stored outside in direct sunlight for a minimum of 5 years without degradation; if necessary an ultra-violet inhibitor shall be added to the resin for this purpose.

GRP fittings shall be fabricated from cut and mitred straight pipe, which has already been tested, the mitre joint being over wrapped with woven roving and chopped strand fibre mat thoroughly impregnated with resin. The design and fabrication of fittings shall be such as to give equal strength and corrosion-resistant properties to that of straight pipe. Flanges shall be drilled to PN 10, unless otherwise stated.

The Contractor shall advise the manufacturer of the climatic and transporting conditions at the site of the Works and shall seek his advice on the storage of GRP materials on site. Subject to the Engineer's approval this advice shall be followed at all times.

Except where otherwise specified or approved by the Engineer pipes shall be jointed with push-fit couplings appropriate for the chosen design pressure. Couplings shall withstand the various tests specified in the applicable standards.

The pipes shall be supplied in standard length of 6,00 m with stiffness class SN 5000 (5 kPa), pressure class PN 1 for pipes laying in depth up to 4 m. Pipe sections to be installed deeper than 3 meter shall be of class SN 10.000 (10 kPa). Pipes may be cut to required length, chamfering the cut end to fit with the coupling. Non pressure field closures may be used with closure coupling.

Material that does not meet the required conditions must not be taken over and installed, but must be replaced with the proper one at the expense of the manufacturer. When handling, transporting, storing and installing pipes and pipe equipment, they should be protected from direct sunlight. They should be stored in a sheltered, well-ventilated pile so that no part of the material is exposed to sunlight.

During installation, the pipes are placed on a compacted substructure and a bed of fine-grained sand fraction recommended by the manufacturer. The pipe is backfilled with the same material in a layer of 300 mm above the top of the pipe immediately after installation with manual compaction of the layer. The joints, which will be exposed during the pressure test, shall be shielded with a hemp cloth placed at least 0.50 m above the pipe until the final backfilling begins. Installation and testing of the system should be in accordance with EN 1610. Prior to installation, each pipe should be carefully inspected and checked for correctness, and the inner and outer surfaces of the pipe should be cleaned. Pipes can be cut with a fine saw if necessary. The pipes are connected according to the manufacturer's instructions, with original couplings in which rubber rings are inserted, which ensures the watertightness of the joints. Pipes laid in the trench should be straight and without tension. Changing the direction on the coupling heads is allowed in the value of 2-3 °. GRP pipes will be installed only on sections defined by the main project and studies of laying pipelines in main roads. Pipes and fittings shall be indelibly marked prior to laying to indicate the correct initial jointing allowance.

E.3.5 Ductile Iron (DI) Pipes and Fittings

E.3.5.1 Standards

The Contractor shall carry out the works described in accordance with the appropriate standards or equivalent local or international standards. The main standards are, but shall not be limited by the following:

Pipes and Fittings

- ISO 2531 Ductile iron pipes, fittings, accessories and their joints for water applications;
- EN 545 Ductile iron pipes, fittings, accessories and their joints for water pipelines -Requirements and test methods;
- EN 598 Ductile iron pipes, fittings, accessories and their joints for sewerage applications - Requirements and test methods;

- ISO 16631 Ductile iron pipes, fittings, accessories and their joints compatible with plastic (PVC or PE) piping systems, for water applications and for plastic pipeline connections, repair and replacement;
- ISO 10803 Design method for ductile iron pipes;
- ISO 7186 Ductile iron products for sewerage applications;
- ISO 1804 Restrained joint systems for ductile iron pipelines - Design rules and type testing.

QC standards

- EN 10204 Metallic products - Types of inspection documents

E.3.5.1.1 Materials

All pipes and fittings and accessories shall be made from ductile cast iron, also called nodular or spheroid graphite cast iron, characterised by the presence of graphite in the spheroid state in sufficient quantities to impart the mechanical characteristics defined in the respective standards.

Pipes, fittings and accessories must not have any defects likely to be detrimental to their use.

Unless otherwise specified minimum pressure classes shall be as follows:

Nominal Diameter DN [mm]	Pressure class
60 to 300	C40
350 to 600	C30
700 to 2000	C25

Minimum wall thicknesses for pressure classes shall be in accordance with EN545 and ISO 2531. The tolerances on thickness and on masses shall not exceed the tolerances given in ISO 2531.

E.3.5.2 Joints

E.3.5.2.1 Socket and Spigot Pipes and Fittings

All buried pipes and fittings shall, unless otherwise indicated, be of the socket and spigot type with coatings as specified in Sub-Clause E.3.10.4. The joint to be used shall be the automatic push-in joint. The joint is made watertight by the compression of a rubber gasket.

Ductile iron pipes and equipment can be used for pressure lines from new and existing pumping stations. Pipe installation and quality should be in accordance with EN 545: 2001. Pipes shall be of class K9 or higher if local conditions require. Internal protection shall be made of cement mortar in accordance with the mentioned norms. The minimum thickness of the cement layer should be 5 mm for diameters up to 600 mm, and 6 mm for diameters larger than 600 mm. External protection shall be from zinc coating and asphalt-based coating. Internal and external protection shall be performed by the manufacturer. Joints in underground installations shall, wherever possible, be socket joints. Socket joints will be protected with an epoxy layer. The joint gasket shall be recommended by the pipe manufacturer and supplied with the pipe.

The Contractor must ensure that the pipes and equipment meet the requirements of positive and negative pressure. Where necessary, pipe joints must be laid longitudinally using TYTON joints in accordance with DIN 28603 or similar. Valves, pipe fittings, air valves and other elements for installation must comply with the above standards. The quality of pipes and equipment shall be approved by an independent institution, which is authorised in accordance with EN 598: 2007 + A1: 2009 or for which the relevant comparable certificate is valid locally. Pipes and equipment shall be laid carefully, in a straight line and according to the given slope, using the provided facilities for setting down the parts when they need to be laid in the trench. Any pipe that is not aligned or that is not properly installed or damaged shall be

reinstalled or replaced at the expense of the Contractor. Pipes that will be used for structures without trenches and without additional protective pipes will be additionally protected from the outside with thermal protection. Rubber gasket materials for drinking water pipelines shall be of EPDM (Ethylene Propylene Diene Monomer) in accordance with the requirements of EN 681-1, type WA.

Rubber gasket materials for waste water pipelines shall be of NBR (Acrylonitrile Butadiene Elastomer).

The storage conditions for the gaskets shall be as follows:

- the storage temperature should be between + 5 °C and + 25 °C. If they are stored at low temperature, care should be taken not to deform gaskets when handling them. They should be brought to about 30 °C for long enough to give them original flexibility before being used. At changes in direction (bends) or nominal diameter (reducers) and when branching (tees) is constructed or at pipeline ends (blank flanges) joints shall provide restraint if the pipe is not secured according to Section E.2.7.6.10.

E.3.5.2.2 Flanged Pipes and Fittings

All non-buried pipes and fittings (in pumping stations, etc.) shall, unless otherwise specified, be flanged with internal and external coatings as specified in Section E.3.10.4.

Flanges shall comply with EN 1092-2. Bolts, nuts and washers shall be as specified in Section E.3.11.2.

For flanged joints of drinking water pipelines the gasket shall be made of EPDM (Ethylene Propylene Diene Monomer) in accordance with the requirements of EN 681-1, type WA. The gaskets for flanged joints shall be reinforced by means of a metallic ring.

Where flanged connections are covered by backfill, all flanged joints shall be wrapped in PE-sheets.

E.3.5.3 Transport and Storage

During transport pipes shall be solidly supported not only under the lower layer and between the layers, but also laterally and at the ends and the top in wooden crates to prevent accidental damage. Storage on site shall be on a raised floor with support frames so that the sockets do not touch the ground. Storage can be either head to tail storage or all pipes pointing in the same direction. The storage of all pipes shall be carried out in strict accordance with the manufacturer's instructions.

E.3.5.4 Re-Rounding and Cutting of Pipes

Pipes, which have been roughly handled, can have an ovalisation at the spigot end, which prevents a correct assembly of the pipeline. Such ovalisation may be corrected with special tensioning equipment to the approval of the Engineer. The application of correction methods has to ensure that no damage will be caused to the preventive coating of the pipes.

In general no cutting of ductile iron pipes, fittings and accessories on site is allowed. All delivered pipes shall provide a thoroughly proper preventive coating according to the defined requirements.

E.3.6 Cast Iron (CI) Pipes and Fittings

E.3.6.1 Standards The Contractor shall carry out the works described in accordance with the appropriate standards or equivalent local or international standards. The main standards are, but shall not be limited by the following:

Pipes and Fittings

- ISO 6594 Cast iron drainage pipes and fittings — Spigot series;
- EN 10242 Threaded pipe fittings in malleable cast iron;
- ISO 6594 Cast iron drainage pipes and fittings — Spigot series;

QC standards

- EN 10204 Metallic products - Types of inspection documents

E.3.7 Steel Pipes and Fittings

E.3.7.1 Standards

The Contractor shall carry out the works described in accordance with the appropriate standards or equivalent local or international standards. The main standards are, but shall not be limited by the following.

Steel pipes

- EN 10224 Non-alloy steel tubes and fittings for the conveyance of water and other aqueous liquids - Technical delivery conditions;
- EN 10255 Non-Alloy steel tubes suitable for welding, threading and other joining methods - Requirements and test methods;
- EN 10220 Seamless and welded steel tubes - Dimensions and masses per unit length;
- EN 10216 Seamless steel tubes for pressure purposes - Technical delivery conditions;
- EN 10217 Welded steel tubes for pressure purposes - Technical delivery conditions;
- EN 10226 Pipe threads where pressure tight joints are made on the threads;
- EN 10311 Joints for the connection of steel tubes and fittings for the conveyance of water and other aqueous liquids;
- DIN 2460 Steel water pipes and fittings;
- EN ISO 3183 Petroleum and natural gas industries - Steel pipe for pipeline transportationsystems.

Fittings

- EN 10253 Butt-welding pipe fittings;
- EN 10241 Steel threaded pipe fittings;
- DIN 2460 Steel water pipes and fittings.

Steel Names and QC Standards

- EN 10027 Designation systems for steels;
- EN 10204 Metallic products - Types of inspection documents.

Material Tests

- EN 10204 Metallic products - Types of inspection documents;
- EN ISO 6892 Metallic materials - Tensile testing;
- EN ISO 6506 Metallic materials - Brinell hardness test;
- EN ISO 6508 Metallic materials - Rockwell hardness test;
- EN ISO 7438 Metallic materials - Bend test;
- EN ISO 5173 Destructive tests on welds in metallic materials - Bend tests;
- EN ISO 5178 Destructive tests on welds in metallic materials - Longitudinal tensile test on weld metal in fusion welded joints:

Corrosion Protection & Coating See Section E.3.10.

Welding

- EN ISO 9606 Qualification testing of welders - Fusion welding;
- EN ISO 15607 Specification and qualification of welding procedures for metallic materials,
- EN ISO 14731 Welding coordination - Tasks and responsibilities;
- EN ISO 3834 Quality requirements for fusion welding of metallic materials;
- EN ISO 9692 Welding and allied processes - Types of joint preparation;
- EN 287 Qualification test of welders;
- EN 288
- EN 1011 Welding - Recommendations for welding of metallic materials;
- EN 5817 Welding - Fusion-welded joints in steel, nickel, titanium and their alloys (beam welding excluded) - Quality levels for imperfections;
- DIN 1910 Welding.

Welding Consumables

- EN ISO 2560 Welding consumables - Covered electrodes for manual metal arc welding of non-alloy and fine grain steels – Classification;
- EN ISO 14341 Welding consumables - Wire electrodes and weld deposits for gas shielded metal arc welding of non-alloy and fine grain steels - Classification;
- EN ISO 14171 Welding consumables - Solid wire electrodes, tubular cored electrodes and electrode/flux combinations for submerged arc welding of non-alloy and fine grain steels – Classification;
- EN ISO 636 Welding consumables - Rods, wires and deposits for tungsten inert gas welding of non- alloy and fine-grain steels – Classification;
- EN ISO 20378 Welding consumables - Rods for gas welding of non-alloy and creep-resisting steels - Classification;
- EN ISO 20544 Welding consumables - Technical delivery conditions for filler materials and fluxes - Type of product, dimensions, tolerances and markings;
- EN 12074 Welding consumables - Quality requirements for manufacture, supply and distribution of consumables for welding and allied processes.

Welding Tests

- EN ISO 17637 Non-destructive testing of welds - Visual testing of fusion-welded joints;
- EN ISO 4136 Destructive tests on welds in metallic materials - Transverse tensile test;
- EN ISO 5173 Destructive tests on welds in metallic materials - Bend tests;
- EN ISO 23277 Non-destructive testing of welds - Penetrant testing - Acceptance levels;
- EN ISO 17638 Non-destructive testing of welds - Magnetic particle testing;
- EN ISO 23278 Non-destructive testing of welds - Magnetic particle testing - Acceptance levels;
- EN ISO 17636 Non-destructive testing of welds - Radiographic testing;
- EN ISO 11666 Non-destructive testing of welds - Ultrasonic testing – Acceptance;
- EN ISO 23279 Non-destructive testing of welds - Ultrasonic testing - Characterization of discontinuities in welds;
- EN ISO 17640 Non-destructive testing of welds - Ultrasonic testing - Techniques, testing levels, and assessment;

- EN ISO 10893 Non-destructive testing of steel tubes;
- EN ISO 17635 Non-destructive testing of welds - General rules for metallic materials;
- EN ISO 10675 Non-destructive testing of welds - Acceptance levels for radiographic testing;

E.3.7.2 General

Steel pipes and fittings shall be factory made. Factory welding of longitudinal and spiral seams shall be an automatic submerged arc welding process, except for smaller pipe diameters as detailed under Manufacture in this clause. The ends of pipes, fitting and specials shall be fully prepared for jointing by the specified method, prior to delivery to site.

Internal and external corrosion protection systems shall be applied at the factory only. On-site application shall only be admissible protection systems at welded joints, and such shall be supplied to the site in adequate quantities.

E.3.7.3 Materials and Dimensions

All pipes, and fittings and accessories shall be made from steel of quality and dimensions to impart the mechanical characteristics defined in applicable standards and shall meet the pressure class required for the specific application.

Dimensions of pipes shall be in accordance with EN 10220. Pipes and fittings must not have any defects likely to be detrimental to their use, and shall be supplied with an inspection certificate according to EN 10204.

Steel pipes shall be usually supplied in lengths of 6 m or 12 m, but with a maximum length of 14 m. Steel pipes for the conveyance of water shall be made of L 235 (1.0252) or L 355 (1.0419), according to EN 10027-1 and EN 10027-2 respectively.

Materials for applications other than conveyance of drinking water are only admissible after approval of the Engineer. For coatings of pipes see section E.3.10.

E.3.7.4 Marking, Tolerance Class and Certification

Marking of the pipe shall be made in white reflective weather resistant paint at one end of the pipe and indicate the information as specified in Section E.2.3.3. and following information:

- Pipe number (individual and selected consecutively, no two pipes shall bear the same number). The pipe number shall ensure full traceability to test reports;
- Tolerance symbols for pipes ≥ 500 mm. The pipe certification package shall comprise the Manufacturer's Certified Test Reports and inspection certificate (i.e. certified to EN 10204, or equivalent) including, upon request, Independent Inspectors Reports and third party certificates, all marked with the supply contract number and containing:
 - Heat and product analysis results;
 - Mechanical test results;
 - Non-destructive examination reports with a statement of method used;
 - Statement of compliance with visual and dimensional checks;
 - Statement of manufacturing process and type of heat treatment;
 - Statement of compliance with hydrostatic test requirements including test pressure;
 - Inspection certificates and reports for surface treatments. Pipes for laying as part of a trunk main shall be supplied with ends prepared for butt-welding of joints.

The individual sections of manifolds shall be prefabricated in required lengths. Whenever feasible, welding on site shall be avoided and shall only be admissible in particular cases, and after approval of the Engineer.

E.3.7.5 Laying of Pipes

Laying of pipes shall be in accordance with the requirement as specified in Section E.2.7 and with the instruction of the manufacturer.

E.3.7.6 Welding of Pipelines

The Contractor shall provide all necessary personnel, equipment and materials. The equipment shall include, but not be limited to:

- Welding machines and generators suitable for pipeline welding;
- Preheating equipment which ensures uniform preheating around the whole circumference of welding ends;
- Post weld heat treatment equipment;
- Internal and external line-up clamps (the external clamp shall be hydraulically operated);
- Protective canopies (or umbrellas and wind shield collars) so that welding can be carried out even in relatively bad weather;
- Weather proof, insulating mats for the thermal insulation of girth welds (at least 1,5 x d wide). The Contractor shall supervise the site, the welders and their work during the entire working period. For this purpose the Contractor shall use a qualified and certified welding specialist. All welding certificates and tests reports shall be submitted to the Engineer.

E.3.7.6.1 Materials

The weld filler metal selected shall give a weld metal matching the base metal properties as closely as possible. The yield strength of consumables shall neither overmatch the base material yield strength by more than one level stated in the respective standards, nor shall undermatching be allowed.

Attention shall be paid to obtaining a good working environment such as selection of low smoke developing consumables etc.

E.3.7.6.2 Welding Processes

Acceptable welding processes are:

- Shielded Metal Arc Welding (Stick) SMAW
- Gas Tungsten Arc Welding (TIG) GTAW
- Gas Metal Arc Welding (MIG/MAG) GMAW
- Flux Cored Arc Welding FCAW The use of welding processes other than those listed above is permitted only with the prior approval of the Engineer. Processes may be used in combination if the same combination and sequence of processes have been qualified by the welding procedure qualification test.

The welding shall be inspected by an independent inspection company engaged by the Contractor. It is the sole responsibility of the Contractor to document that welding and welding inspection fulfil all specified requirements.

E.3.7.6.3 Welding Procedure Qualification

The Contractor shall submit detailed welding procedure requirements complying with the standards. All dimensions, all combinations of materials to be joined and all repair welding shall be covered by the procedure requirements. The procedure requirements are subject to the approval by the Engineer.

The Engineer may, at his sole discretion, approve the use of already established, sufficiently tested and documented procedures not more than 2 years old. Transfer of welding procedure qualification records from one contractor to another is not permitted.

For each procedure requirements and prior to start of production welding, the Contractor shall carry out welding of test joints under site conditions following all of the details of the approved procedure specifications.

The qualifications test shall be carried out on steel with the highest specified minimum yield strength / maximum carbon equivalent which is expected to be covered by the Welding Procedure Specification. All the results from the procedure qualification records shall be submitted to the Engineer for approval of welding procedures.

E.3.7.6.4 Qualification of Welders and Welding Operations

Only skilled welders and welding operators who can document qualifications relevant for pipeline welding will be accepted by the Engineer. Prior to the performance of any production welding operators shall qualify for the relevant welding procedures according to EN ISO 9606-1.

The qualification tests are acceptable if they meet the requirements for visual examination, destructive testing and for radiographic examination as specified in the respective standards. The testing shall be carried out by an approved laboratory at the Contractor's expense. Welder and welding operator performance test certificates shall be issued and kept on site during the whole working period.

Welder and welding operator qualification tests may be performed together with welding procedure qualification tests.

These certificates are only valid for 6 months after the last welding

E.3.7.6.5 Welding Preparation

Items material grades, wall thickness and ratings shall conform to the requirements laid down in the applicable Drawings and Employer's Requirements.

Surfaces to be welded have to be completely clean to avoid deterioration of weld quality by any oxide, oil, grease or other contaminations or impurities. Raw edges after oxygen cutting shall be ground to remove any residual oxides, dross, or slag. Edges before welding shall be clamped in position with suitable mechanical devices.

Each pipe or component shall be visually inspected to ensure that it has not sustained any visually determinable damage. Disposition of damaged items shall be resolved in consultation with the Engineer.

All requirements for welding preparation contained in the qualified welding procedure Employer's Requirements shall be strictly adhered to.

E.3.7.6.6 Weld Pointing

Weld points shall be made by skilled welders as specified above and under conditions required for welding as specified below:

- electrodes shall be dried and conserved according to the recommendations of the producers;
- pre and post-heating shall be applied where necessary;
- length of weld points shall be greater than 30 mm. The parent metal dilution shall be limited to avoid risk of weld metal deposited cracks. Backward welding shall be carried out at the end of each bead to properly fill the craters of welding pass end and, thus, avoid incipient cracks. Any cracked tack weld must be removed before the welding operation.

Fastening of welded edges shall ensure compliance with alignment tolerances during all the welding operations.

E.3.7.6.7 Welding Workmanship

All welding shall be performed by qualified welders and strictly in accordance with qualified welding procedures.

Welding shall be suspended by the Contractor when prevailing weather conditions will impair the quality of the work, e.g. airborne moisture, blowing sand, high winds or thunderstorms.

Vibration inducing operations carried out in the vicinity of welded plates are prohibited during welding operations.

Stray arching outside the weld groove is not permitted. Should stray arching outside this area occur, this shall be brought to the attention of the Engineer who may require any such damaged section to be repaired or cut out at the Contractor's expense.

Earth connections for the welding shall always be positioned in the centre of the joint during root and cap-bead laying. They shall be mechanically or magnetically connected to the pipe.

Each pass shall be completed around the whole circumference before the next pass is started.

The position of start / stop on subsequent passes shall not be identical. Upon completion of the cap bead, the weld and the pipe surface shall be cleaned of weld spatter and other deposits, and shall then be wrapped with a dry, waterproof insulating mat to ensure a slow cooling of the weld zone and to give protection against rain.

E.3.7.6.8 Cleaning after Welding

The surface shall be dry and free of oil, grease, soil and concrete residues. All loose rust and mill-scale shall be removed by wire brushing immediately before welding inspection. On straight pipes, brushing shall be done mechanically using sharp brushes to avoid polishing of the steel surface. Therefore, a stock of readily accessible new brushes is required.

Welds fabricated with basic filler metals shall be washed with fresh water.

Cleaning by sandblasting is allowed as an alternative.

E.3.7.6.9 Post Weld Heat Treatment (PWHT)

PWHT of weld seams shall only be carried out if specified in the approved welding procedure or where this is indicated in the project material. PWHT procedures shall be approved by the Engineer.

E.3.7.6.10 Identification of Weld Seams

Every girth weld shall be numbered by the Contractor in accordance with a system to be approved by the Engineer. This number shall be painted on the pipe coating on one side of the joint between 0,5 m and 1,0 m from the seam together with the pipe number and pipe length to facilitate completion of the pipe book.

For each pipeline and each pressure test section, the Contractor shall fill out pre-printed forms and enter these in a pipe log. As the work progresses, the Contractor shall present the pipe log forms to the Engineer. Before the start of a pressure test the completed pipe log for the section in question shall be handed over to the Engineer.

E.3.7.6.11 Closing of Pipe Ends

During welding on a pipeline segment all open ends of that segment shall be kept closed with a plug or a cap.

At interruption in the pipeline construction, the Contractor shall close the ends of the pipe strings. The closure shall be tight enough to prevent any entry of foreign matter into the pipe.

Plugs or caps must not be fixed by welding or by any other method which damages the pipe. They shall be securely attached to the pipe and shall remain in place until the string is laid.

E.3.7.6.12 Welding of Fittings

Fittings shall be for butt-welding. The wall thicknesses shall harmonise with the PN of the adjacent straight pipe. Flanges for butt-welding shall be according to ISO 7005 and/or EN 1092 or equivalent standard.

E.3.7.6.13 Welding, Testing and Inspection

Examination shall be performed according to applicable standards approved by the Engineer and the following inspection methods:

- Radiographic examination according to ISO 17636 and EN ISO 10675;
- Ultrasonic examination according the standards EN ISO 10893;
- Magnetic particle examination according to EN ISO 10893;
- Liquid penetrant examination according to ISO 3452;
- Visual examination according to EN ISO 17637 ;
- Hardness measurement according the standards. The Contractor shall engage a qualified independent inspection company which shall perform, evaluate and document all welding inspection. The inspection company shall be approved by the Engineer.

All non- destructive examination shall conform to the requirement of the adequate method standard and the Employer's Requirements. Procedures shall be submitted to the Engineer for approval.

Document Requirements The following documents shall be submitted to the Engineer for approval:

Before examination:

- Certificates for welding personnel;
- Welding procedures;
- Report forms;
- Request for deviations, if any, from specified requirements.

During examination:

- Examination reports with enclosed field reports and films.

E.3.7.7 Other Jointing Methods

E.3.7.7.1 Threads

Steel pipes with nominal diameters up to and including 150 mm may be threaded (female or male) at both ends and provided with a detachable screwed coupling attached to one end. Threads shall comply with EN 10226, BSPT/P or ANSI B1.20.1, NPT/S. Couplings shall be made from similar material to that of the pipes.

E.3.7.7.2 Flanges

Where flanges are required they shall be forging or made from steel plate meeting the steel specification of the pipe material. Flanges shall be weld-on type and drilled to the application, PN 10 or PN 16.

Flanges shall comply with the standards stated in Section E.3.11.1.

E.3.8 Galvanised Iron (GI) Pipes and Fittings

E.3.8.1 Standards

Galvanised pipes and fittings (in accordance with the appropriate EN Standards or equivalent standards) shall only be used when approved by the Engineer. The Contractor shall carry out the works described in accordance with the appropriate standards or equivalent local or international standards. The main standards are, but shall not be limited by the following.

- EN ISO 1461 Hot dip galvanized coatings on fabricated iron and steel articles - Specifications and test methods
- EN 10240 Internal and/or external protective coatings for steel tubes - Specification for hot dip galvanized coatings applied in automatic plants;
- EN 1179 Zinc and zinc alloys - Primary zinc

E.3.8.1.1 Pipes

Galvanised iron pipes shall be manufactured according to ISO 1461 and EN 10255. The galvanisation shall be by hot-dip process according to EN 10240 and EN 1179 and shall satisfy the copper sulphate test procedure according to EN ISO 1460.

All pieces shall be straight, cleanly finished, free from cracks, surface flaw lamination and other defects and shall have a reasonably smooth surface. The overall pipe length, with one socket fitted, is to be 6 m plus or minus 150 mm.

E.3.8.1.2 Joints

Galvanised steel pipes and fittings shall be supplied with either flanged ends or with threaded ends.

Where flanged joints are specified for use with galvanised steel pipe and fittings the flanges shall be in accordance with Section E.3.11.1.

Threaded sockets shall be in accordance with ISO 228-1, EN 10226, ISO 65 or equivalent. Screw threads shall be clean, well cut and square with the axis of the pipe and be free from excessive burrs. The end of each socket shall be chamfered internally.

E.3.9 Stainless Steel Pipes

E.3.9.1 Standards

The Contractor shall carry out the works described in accordance with the appropriate standards or equivalent local or international standards. Main applicable standards are, but shall not be limited by the following:

- EN ISO 1127 Stainless steel tubes - Dimensions, tolerances and conventional masses per unit length;
- EN 10296-2 Welded circular steel tubes for mechanical and general engineering purposes - Technical delivery conditions - Part 2: Stainless steel;
- EN 10297-2 Seamless steel tubes for mechanical and general engineering purposes - Technical delivery conditions - Part 2: Stainless steel;
- EN ISO 14343 Welding consumables - Wire electrodes, strip electrodes, wires and rods for arc welding of stainless and heat resisting steels;

E.3.9.2 Materials and Dimensions

All pipes, and fittings and accessories shall be made from stainless steel of quality to impart the mechanical characteristics defined in the respective standards.

The following stainless steel qualities shall be used according to EN 10027.

EN 10027	Specification	ASTM / AISI	UNS-Number
Material No.			
1.4301	X5CrNi18-10	304	S30400
1.4571	X6CrNiMoTi17-12-2	316Ti	S31635
The following shall be used for minor quality requirements, only after prior approval by the Engineer.			
1.4401	X5CrNiMo17-12-2	316	S31600
1.4404	X2CrNiMo17-12-2	316L	S31603
1.4436	X3CrNiMo17-13-3	316	S31600

The tolerances on thickness and on masses shall not exceed the tolerances given in EN 1127.

E.3.9.3 Welding

For welding of stainless steel pipes and fittings in general, the requirements stated in Section E.3.7.6 shall apply.

Only the welding methods WIG (Wolfram-Inert-Gas) and MAG (Metal-Active-Gas) shall be applied. Only suitable equipment that guarantees a professional performance is to be used for this purpose.

The contractor has to ensure that the material combination in the area of the welding zone will not be negatively altered and that intercrystalline corrosion will not develop. For this reason, only certified welding additions according to EN ISO 14343 and a shielded arc atmosphere shall be used that is in accordance with the material.

As far as possible, welding, edging and drilling shall be performed in the workshop under controlled conditions. Permanent protection from corrosion is to be guaranteed through a pickling treatment in the pickling bath with the correct acid consistency and temperature and through a follow-up passivation. Local pickling treatment and passivation at the construction site is only permitted in special cases. Pickling treatment and passivation have to be certified.

E.3.10 Internal Lining and external Coating of Pipes and Fittings

E.3.10.1 Standards

The Contractor shall carry out the works described in accordance with the appropriate standards or equivalent local or international standards. The main standards are, but shall not be limited by the following:

- ISO 4179 Ductile iron pipes and fittings for pressure and non-pressure pipelines - Cement mortar lining;
- ISO 8179 Ductile iron pipes, fittings, accessories and their joints - External zinc- based coating;
- EN 545 Ductile iron pipes, fittings, accessories and their joints for water pipelines - Requirements and test methods;
- ISO 2531 Ductile iron pipes, fittings, accessories and their joints for water applications;
- ISO 16631 Ductile iron pipes, fittings, accessories and their joints compatible with plastic (PVC or PE) piping systems, for water applications and for plastic pipeline connections, repair and replacement;
- EN 14628 Ductile iron pipes, fittings and accessories - External polyethylene coating for pipes - Requirements and test methods;
- EN 15542 Ductile iron pipes, fittings and accessories - External cement mortar coating for pipes - Requirements and test methods
- EN 10287 Steel tubes and fittings for on and offshore pipelines - External fused polyethylene based coatings;

- EN 10288 Steel tubes and fittings for on and offshore pipelines - External two layer extruded polyethylene based coatings;
- EN 10289 Steel tubes and fittings for onshore and offshore pipelines - External liquid applied epoxy and epoxy-modified coatings;
- EN 10290 Steel tubes and fittings for onshore and offshore pipelines - External liquid applied polyurethane and polyurethane-modified coatings;
- EN 10298 Steel tubes and fittings for onshore and offshore pipelines - Internal lining with cement mortar;
- EN 10300 Steel tubes and fittings for onshore and offshore pipelines - Bituminous hot applied materials for external coating
- EN 10310 Steel tubes and fittings for onshore and offshore pipelines - Internal and external polyamide powder based coatings;
- EN 12068 Cathodic protection - External organic coatings for the corrosion protection of buried or immersed steel pipelines used in conjunction with cathodic protection - Tapes and shrinkable materials;
- EN 14901 Ductile iron pipes, fittings and accessories - Requirements and test methods for organic coatings of ductile iron fittings and accessories;
- EN ISO 22063 Metallic and other inorganic coatings - Thermal spraying - Zinc, aluminium and their alloys;
- DIN 2880 Application of cement mortar lining for cast iron pipes, steel pipes and fitting;
- DIN 30670 Polyethylene coatings of steel pipes and fittings - Requirements and testing;
- DIN 30675-1 External corrosion protection of buried pipes - Part 1: Corrosion protection systems and application for steel pipes;
- DIN 30675-2 External corrosion protection of buried pipes - Part 2: Corrosion protection systems and application for ductile iron pipes;
- DIN 30674-3 Sheathing ductile cast iron pipes - Part 3: Zinc coating with protective sheathing;
- DIN 30674-5 Sheathing ductile cast iron pipes - Part 5: Polyethylene sleeving;
- BS 4164 Specification for coal-tar-based hot-applied coating materials for protecting iron and steel, including a suitable primer,
- AWWA C 203 Coal-Tar Protective Coatings and Linings for Steel Water Pipe;
- AWWA C 213 Fusion-Bonded Epoxy Coatings and Linings for Steel Water Pipe and fittings.

E.3.10.2 General

The Contractor shall provide detailed information and technical documentation of the internal and external protection of pipes, and shall specify the guarantee period of all coatings.

All pipes and fittings shall be factory coated only. Surface shall be free of any impurity, stain, dirt and corrosion prior to application of any coating to guarantee maximum adherence of the coating.

Internal lining of pipes and fittings shall be certified for use for potable water when required. Internal lining shall guarantee that the hydraulic performance of the pipes and fittings shall be maintained long term even if the water was chemically aggressive.

In general, the quality of internal lining and external coatings shall be excellent upon delivery. The Engineer shall not accept pipes with damaged lining and coatings.

E.3.10.3 General Requirements for internal Lining and external Coating

- a) Internal lining and external coating must:
- Be applied on a properly prepared surface;
 - Have sufficient adhesion to the metal surface to effectively resist underfilm migration of moisture;
 - Be sufficiently ductile to resist cracking;
 - Have sufficient strength to resist damage due to handling and soil stress (external coating);
 - Have high UV resistance (external coating);
 - Have high resistance against water, wastewater and sludge and its contents as required (internal lining);
 - Shall be suitable for potable water applications (where applicable) and shall not contain any toxic element or elements soluble in water, or elements susceptible to impart any smell or odour to the water (internal lining);
 - Have properties compatible with any supplemental cathodic protection, in particular:
 - volume resistivity of at least 1013 Ωcm ;
 - high resistance against cathodic alkali;
 - protected against blistering by hydrogen at a negative potential of – 1.100 mV (for aluminium or zinc anodes) or of – 1.600 mV (for magnesium anodes);
 - low moisture absorption and high electrical resistance (external coating);
- b) Each external protective coating must be inspected just prior to lowering the pipe into the ditch and backfilling, and any damage detrimental to effective corrosion control must be repaired;
- c) Each external protective coating must be protected from damage resulting from adverse ditch conditions or damage from supporting blocks;
- d) If coated pipe is installed by boring, driving, or other similar method, precautions must be taken to prevent damage to the coating during installation.

The Contractor shall prove all the above requirements under (a) by test certificates to be submitted to the Engineer and by onsite tests on factory applied coatings and on field joint coatings as described below.

The Contractor shall submit to the Engineer a complete description of the lining and coating systems for approval prior to ordering.

For ductile iron pipes internal lining and external coating refer to Section E.3.10.4. For steel pipes internal lining and external coating refer to Section E.3.10.5.

E.3.10.3.1 Surface Preparation

Before blasting, all oil, grease, mill lacquer and other deleterious material on the surfaces of the metal to be coated shall be removed by suitable means.

In cold weather or any time when moisture tends to collect on the steel, the pipe shall be uniformly warmed for sufficient time to dry the pipe prior to cleaning. The pipe temperatures shall be maintained at least 3 °C above the dew point during the cleaning and coating operations. Pipe temperature shall not exceed 70 °C as a result of preheat.

Pipe surfaces shall be blast cleaned to a blast metal finish. The grade of derusting shall comply with ISO 8501-1 SA 2½. Certain coating systems require a greater degree of cleanliness; in such cases, the degree of cleaning shall be as required by the coating system.

Following cleaning and prior to coating the pipe, abrasive remaining on the outside and loose contamination on the inside of the pipe shall be removed by air blast, vacuum or other suitable methods. If air is used, the air should be dry and free of contaminants, and all particles removed from the surface shall be collected in such a manner as not to contaminate clean pipe.

Following cleaning and prior to coating, the pipe surface shall be inspected for adequate cleaning and surface condition. Pipe not properly cleaned shall be rejected and re-cleaned.

Blast cleaned pipe surfaces shall be protected from conditions that would allow the pipe to flash rust before coating. If flash rusting occurs, affected pipe shall be re-cleaned.

E.3.10.3.2 FBE / FBPE or FBPP Coating

FBE coatings shall be according to AWWA C 213 and comprise of 3 layers:

- a) FBE primer, thickness min. 0,15 mm;
- b) adhesive middle layer, thickness min. 0,15 mm;
- c) FBPE or FBPP top coat, compounded with an inert filler, thickness min. 1,2 mm.

The adhesive middle layer shall be designed to bond together the primer and top layer.

The FBPE/PP top coat shall be formulated to be ultra-violet (UV) resistant for a minimum of 10 years exposure.

E.3.10.3.3 Three-Layer PE / PP Coating

Polyethylene and polypropylene coating shall be according to DIN 30670 and comprise of 3 layers:

- a) electrostatically applied epoxy powder primer, thickness min. 0,2 mm;
- b) chemically modified adhesive applied by extrusion method, thickness min. 0,4 mm;
- c) polyethylene or polypropylene top coat applied by extrusion method, thickness min. 3,0 mm.

The PE/PP top coat shall be formulated to be ultra-violet (UV) resistant for a minimum of 10 years exposure.

E.3.10.3.4 CTE Coating

CTE coating shall be according to AWWA C 203 and comprise of 4 layers:

- a) Synthetic primer, thickness min 0,1 mm;
- b) Coal tar enamel, thickness min 3,0 mm;
- c) Resin-bonded glass fibre inner wrap, thickness min 3,0 mm;
- d) Coal tar saturated resin-bonded porous glass fibre outer wrap, thickness min 6,0 mm.

E.3.10.3.5 Zinc and Bituminous Coating

Zinc coating materials shall be either metallic zinc with a content of at least 99 %, or zinc-rich paint containing at least 85 % zinc in dry film. Zinc coating shall conform to DIN 30674-3. The minimum thickness shall be 40 µm. The minimum application rate shall be 600 g/m².

Metallic zinc-coatings shall be applied at the factory by projecting small droplets of zinc heated to the molten state by means of spray-guns.

Zinc-rich paint coatings shall be applied at the factory by spraying or brushing zinc-rich paint onto the pipe surface.

After zinc-coating, the pipe shall be given a finishing coat based on bituminous products according to DIN 30674-3 compatible with zinc, applied by any proven procedure such as gun-spraying or brush-coating. The mean thickness of the finishing layer shall be not less than 1 mm.

E.3.10.3.6 PU Spray Coat for Field Joints

The PU spray system shall conform to EN 10290 and shall provide a single high-build layer of robust, abrasion resistant polyurethane coating with a minimum thickness of 3 mm. The PU spray system shall guarantee an excellent adhesion to both the pipe substrate and PE/PP factory coating overlap areas.

E.3.10.3.7 Heat Shrinkable Sleeve for Field Joints

Heat shrinkable sleeves shall be designed to provide moisture penetration resistance and corrosion prevention for pipeline field joints and shall comply with DIN 30672.

Heat shrinkable material shall be fabricated from irradiated cross-linked polyolefin pre-coated with an epoxy primer and a hot-melt adhesive (mastic) and shall have a thickness of not less than 125 microns.

The sleeves shall shrink when heated and force the mastic (or adhesive) to flow into the irregularities of the weld.

The shrinking action shall provide a simple, reproducible delivery system for the mastic or adhesive.

When shrunk, the polyolefin sleeve shall provide penetration and abrasion resistance during handling, backfill, and operation of the pipe and shall provide resistance against soil stresses, alkalis, acids, microbes and fungi.

Heat shrinkable sleeves shall be self-priming in nature and shall be bondable substrates including heavy wall pipes, polyethylene, epoxy powder and bituminous coatings.

E.3.10.3.8 Mastic

Mastic shall consist in mineral aggregate and fillers in which the voids in the mineral matrix are overfilled with the adhesives. At ambient temperature, mastic shall be highly viscous under long-duration loading and shall have elastic behaviour when subjected to short-duration loading. Mastics shall be amorphous, pressure sensitive, and tacky, so they bond easily to substrates upon contact and pressure.

Adhesives for “cold mastic” shall be based on butyl rubber, polyisobutylene, synthetic rubbers, or asphalts and shall be self-priming. They shall have “cold flow” characteristics thus being self-healing in the event of a puncture.

Adhesives for “hot mastic” shall be based on bitumen and admixtures in portions and characteristics as needed. Typically hot mastic consists of petroleum hydrocarbons with additives to displace water, inhibit corrosion, enhance adhesion and control flow.

“Marine mastic” shall be a blend of petrolatum, inert fillers and expanded polystyrene beads, and special wetting additive to enable the product to be used in submerged marine applications. “Marine mastic” shall be non-setting and non-hardening, and shall give neutral buoyancy.

E.3.10.3.9 Reinforced Tape Wraps for Field Joints

Glass fibre reinforced coal tar enamel wrapping shall comply to DIN 30672 and shall comprise of:

- a) Mastic;
- b) Inner tape wrap consisting of hot applied, mineral filled coal tar, reinforced with an inner layer of 50 g/m² glass tissue, spirally wound with overlap, separated from the pipe surface by at least 1 mm thickness of enamel giving a minimum finished thickness of 3,0 mm;

- c) Outer tape wrap consisting of coal tar impregnated, longitudinally reinforced with glass fabric spirally wound giving a minimum finished thickness of 6,0 mm.

Factory tape application shall only be applied using a winding machine.

E.3.10.3.10 Solids Rigid Polyurethane Internal Lining

PUR coatings shall be according to EN 10289 and AWWA C 210. Thickness of liner shall not be less than 0,5 mm. PUR shall consist of two components: one isocyanate-rich solution and one polyol-rich solution (ASTM D 16 Type V), bonded together rapidly by exothermic polymerisation and then forming an solid film after application.

E.3.10.3.11 Cement Mortar Internal Lining

Cement mortar for internally lining water supply pipes shall contain no toxic element or elements soluble in water, neither shall it contain elements susceptible to impart any smell or odour to the water. The characteristics of the mortar, its placing and control shall be in compliance with EN 10298 and DIN 2880. The mortar shall consist of at least one part of Portland cement by weight to 3,5 parts of sand by weight, i.e. a sand / cement ratio smaller than or equal to 3,5. The water cement ration shall not exceed 0,42.

Cement mortar for internally lining sewage pipes shall have a sulphate resistant cement according to EN 10298. The thickness of the liner shall not be less than 10 mm.

E.3.10.4 Ductile Iron Pipes and Fittings

Ductile iron pipes and fittings shall have coating and lining as follows:

Pipes, external coating: zinc-aluminium alloy of 400g/m² (Zn85 Al15), finishing layer of water based acrylic $\geq$ 80 microns (or equivalent) of blue colour for water and finishing layer of epoxy resin of red-brown colour for wastewater

Pipes, internal lining: cement mortar of blast furnace cement for water and high alumina cement for wastewater

Fittings, external coating blue (water) or red-brown (wastewater) epoxy powder with minimum 250 micrometer thickness

Fittings, internal lining cement mortar of blast furnace cement or epoxy, min. 250 μ m for water and epoxy, min. 250 μ m for wastewater

The thickness of the internal cement mortar lining shall be as indicated in the following table:

Diameter	Nominal	Limit deviation
Up to DN 300	4,0 mm	-1,5 mm
DN 350 to DN 600	5,0 mm	-2,0 mm
DN 700 to DN 1200	6,0 mm	-2,5 mm
DN 1400 to DN 2000	9,0 mm	-3,0 mm

E.3.10.5 Steel Pipes

Following external pipe coating systems are allowed for steel pipes:

- Fusion bonded epoxy (FBE) plus fusion bonded polyethylene (FBPE) or polypropylene (FBPP) top coat, or;
- Three-layer polyethylene or polypropylene (3-LPE / 3-LPP), or;
- Primer plus coal tar enamel (CTE) plus 2 reinforced tape wraps

Following internal pipelining systems are allowed:

- For potable water applications: Cement mortar of blast furnace cement, or otherwise

- b) 100% solids rigid PU solvent free spray, or
- c) rich metallic zinc spraying.

Steel pipes and fittings shall receive their coating and lining in the manufacturer's works prior to shipping. The thickness of the internal cement mortar lining shall be as indicated in the following table.

Diameter	Nominal	Limit deviation
Up to DN 250	4,5 mm	-1,5 mm
DN 300 to DN 600	6,0 mm	-2,0 mm
DN 700 to DN 900	8,0 mm	-2,0 mm
DN 900 to DN 1200	10,0 mm	-2,0 mm
DN 1400 to DN 2000	14,0 mm	-2,0 mm

E.3.10.6 Galvanised Steel Pipes

Standard references are EN 10240 and EN 10255 or equivalent. Pipes and fittings shall be hot dip galvanised. Minimum thickness shall be 50 µm. The coating shall be homogeneous.

E.3.10.7 Field Application

Coating and lining shall be realised at the Manufacturer's work only. Field coating is only admissible in exceptional cases and after approval of the Engineer. Pipe inspection shall be carried before any field coating. The pipe surface shall be inspected for surface contamination or surface imperfections. If any pipe cannot be coated, or is otherwise questionable, the segment shall be replaced.

E.3.10.7.1 Packing, Delivery, Storage

All coating materials, including repair or patch materials shall be packaged in suitable and approved containers. The containers shall be plainly marked with the name of the Manufacturer, type of material and batch or lot number where applicable. Bulk shipments shall be allowed provided the above information is included in the bill of lading.

The coating material shall be packaged in containers suitable to keep the contents clean and dry during handling, shipping and storage. Storage and handling conditions shall be in accordance with the Manufacturer's recommendations.

Precautions shall be taken during the handling, shipping and storage of all materials to prevent damage to the containers that would result in contamination of the coating materials. All contaminated, or otherwise damaged materials shall be discarded.

E.3.10.7.2 Priming

Immediately after cleaning, all blasted surfaces shall be free of dust, grit and other foreign material and shall be primed by brushing, spraying or other suitable means to produce an effective bond between the metal and subsequent coating. No primer shall be applied to a wet surface.

The use of primer that becomes contaminated with foreign substances or has thickened through evaporation of the solvents shall not be permitted.

The minimum and maximum allowable drying time of the primer between application of primer and application of the coating shall be in accordance with instructions issued by the Manufacturer of the primer. If the coating is not applied within the maximum allowable time after priming as required, the pipe shall be re-cleaned and re-primed.

After application, the primer coat shall be uniform and free from floods, runs, sags, drips or bare spots. Any bare spots shall be re-primed. All runs, sags, floods or drips shall be removed by brushing or scraping and the bare areas, if any,

shall be retouched. Suitable measures shall be taken to protect wet primer from contact with moisture, dust or other foreign matter.

E.3.10.7.3 CTE Application

Coating materials may be delivered in hot bulk or solid forms. The coating shall be heated in approved heating kettles equipped with accurate and easily read thermometers, mechanically agitated, and covered with proper lids.

The coating shall be maintained moisture and dirt free at all times prior to and at the time of heating and application.

The coating shall be loaded into the kettles in pieces of suitable size for the melting equipment used. When the Contractor receives hot material in bulk, the holding kettles shall be operated in accordance with the Manufacturer's instructions.

In heating the coating material, the charge will be melted and brought to application temperature without injury to the coating material. The temperature of application shall not exceed that which is recommended by the Manufacturer.

The primed pipe surface shall be dry and clean at the time the coating is applied.

External coating shall be applied by spraying, flooding, or pouring in such a manner as to maintain the specified thickness. The coating shall overlap the preceding spiral, producing a continuous coat free from defects.

E.3.10.7.4 Application of Tape Inner Wrap

The inner wrap shall be applied directly onto the primed pipe surface with appropriate dispensing and tensioning equipment.

The inner wrap shall be spirally applied with overlap widths and application tensions required and/or recommended by the Manufacturer. The minimum overlap shall not be less than 1 cm. The minimum overlap at the end of a roll of tape shall be 15 cm or more.

The applied inner wrap shall conform tightly to the pipe surface, shall be free of voids and wrinkles and shall be smooth.

When a new roll of tape is started, the end lap of the splice shall overlap the previous roll. This splice shall be smooth and placed so as to maintain the continuity of the inner wrap coating

E.3.10.7.5 Application of Tape Outer Wrap

The outer wrap is applied directly over the inner wrap using the same type of mechanical tape tensioning equipment.

The overlap of the outer wrap shall not be applied directly over the lap of the inner wrap under any circumstances.

The outer layer may be applied at the same time as the inner layer

E.3.10.7.6 PU Spray Coat for Field Joints

PU spray coating shall be carried out by a hydraulic airless high pressure PU machine to guarantee an excellent material mix.

E.3.10.7.7 Heat Shrinkable Sleeve for Field Joints

To ensure mastic fluidity and full adhesive bonding the field joint area must first be pre-heated, to between 60 – 230 °C, depending on the mastic type, prior to sleeve installation. Heat induction shall guarantee rapid, uniform heating around the full 360 degree pipe circumference and over a controlled bandwidth by a "direct-to-metal" non-contaminating heat source, which ensures total mastic fluidity without over/under heating.

Sleeve shrinkage by manual gas torch heating methods shall only be applied for other than circumference weld seams. Sleeves shrinkage shall then be accomplished by using manual gas torch heating methods. Shrinking shall start at the top

centre of the sleeve working toward one end. The torch shall be moved to avoid burning the sleeve. After this, shrinking shall continue circumferentially from the centre to the opposite end. The sleeve has conformed to the pipe when mastic flow is evident at the sleeve edges. Once fully shrunk the sleeve shall be 'rolled' to remove any residual air pockets at the mastic / substrate interface, typically found around the weld bead and factory coating edges.

E.3.10.7.8 Hot Mastic for Field Joints

Mastic mix materials shall be heated in a re-melt kettle to a temperature of approximately 175 to 190 °C or as specified by the manufacturer. Cooling shrinkage may be kept to a minimum if material temperatures are held to the suggested range.

In charging the re-melt kettle, the mastic level shall be maintained such that the paddle blades are visible at the top of their rotation. The unit may be used as a continuous mixer by charging the cold material from the back end while drawing hot material from the gate.

Accurate portable thermometers shall be readily available and used for checking mastic temperatures prior to moulding.

If it should become necessary to hold mastic mix material in the kettle for an unusual length of time, the lid should be closed, the fire decreased and a small amount of asphalt added to replace asphalt driven off by the continued application of heat.

The mastic mix form, or mould, shall consist of a pre-cut section of sheet metal wrapped over the field joint mould area and extending back over the plant applied concrete coating, if any. The form shall be securely strapped or banded at each end.

The pre-cut opening at the top shall be opened and mould shall be filled with mastic mix, being carefully agitated or vibrated and formed to assure complete filling and the elimination of voids or honeycomb within the joint. After filling the mould, the opening shall be strapped shut and at this time water cooling may be used. The number of straps or bands shall be chosen dependent upon the size or weight of the joint being installed.

E.3.10.7.9 Tape Coating Field Joints, Fittings, Connections

Primer respectively mastic shall be applied according to the above Sections.

Strips of wrapper shall be cut according to size of pipe (multiple strips may be required to cover the entire patch area). Length of wrapper should be 4 times the diameter of the pipe.

The wrapper shall be slipped under pipe and ends shall be pulled above pipe on both sides, leaving about 2,5 cm distance from bottom of pipe to wrapper.

Molten mastic shall be poured on top 1/4 of pipe from one side of pipe to other. Mastic will flow down and around the pipe surface.

When mastic moves to the bottom of the pipe, the wrapper shall be seesaw loosely with an upward and downward motion to assure proper thickness.

The wrapper shall be pulled around the hot mastic tightly. A spot of mastic shall be poured on top to stick wrapper to overlap together.

E.3.10.8 Pipe Surface Contamination and Removal

Surface contamination shall mean any foreign material on the pipe surface that is detrimental to the finished coating:

- Organic contaminants such as oils, lubricants, or greases;
- Previously applied coatings;

- Stencil media;
- Soluble salts;
- Adhesive type material such as tape or stickers.

Removal of the contaminants shall be accomplished by cleaning with an acceptable solvent. Criteria of acceptance for a solvent include safety considerations and ability to remove contaminant without leaving a hydrocarbon residue.

If pipe is received containing soluble salts, the pipe shall be cleaned by rinsing of pipe surface with clean fresh water and use of a phosphoric acid wash pre-treatment prior to coating.

E.3.10.9 Inspection and Testing

The entire procedure of applying the protective coating material as herein specified shall be inspected either at manufacturer's premise or onsite. Improperly coated pipes shall be repaired. In case repair is not sufficient, the Engineer shall have the right reject the poorly coated pipe. Re-coating or coating repair that may be necessary shall be done at the Contractor's expense.

E.3.10.9.1 Coating Thickness Measurements

An appropriate and calibrated film thickness gauge shall be used to perform coating thickness measurement.

The coating thickness shall meet or exceed the agreed upon minimum coating thickness. All joints which fail to meet the minimum coating thickness test shall be re-coated or repaired.

E.3.10.10 Repair Procedures

All defects disclosed by the holiday detector and other obvious defects shall be repaired by the Contractor.

Areas of repair to the coating shall be holiday inspected by the Contractor on a 100 % basis. Repairs shall be inspected by holiday testing.

The damaged coating shall be removed from the steel surface. The edge of the cured coating adjacent to the damaged area shall be "feathered" and coated with an appropriate surface conditioning solvent recommended by the coating Manufacturer. This solvent shall be applied in accordance with the Manufacturer's recommendations.

The damaged area shall then be re-coated.

E.3.10.10.1 FBE Coating

Small holidays in FBE coatings may be patched by use of a two part, 100 % solids, liquid epoxy compound specified by the Manufacturer. The damaged area shall be abraded by hand filing or use of carborundum cloth. Application shall be made to a minimum thickness of 0,6 mm and shall overlap the undamaged area a minimum of 1,5 cm. The liquid patch compounds shall not be applied when the pipe temperature is below 10 °C unless provisions are made for heat curing the patch material using methods and temperatures in accordance with procedures recommended by the coating Manufacturer.

E.3.10.10.2 Tape Systems

All holidays detected such as damaged or flawed areas shall be repaired by peeling back and removal of the outer and inner layers from the damaged area.

The holiday area shall then be brushed with primer and a patching tape with a polyethylene backing and butyl adhesive should be applied directly to the defective area in the manner specified by the Manufacturer.

The minimum lap at the damaged area shall be 10 cm all around.

The repaired area shall be tested with a Holiday Detector after the repair is completed.

The repaired area may be covered in cigarette wrap fashion with the outer wrap to a minimum lap of 10 cm beyond the patching tape.

E.3.10.10.3 Cement Linings

Repairs shall be carried out as follows:

- a) The damaged lining shall be cut out to the metal. Edges shall be squared;
- b) The cut-out area and adjoining lining shall be wetted;
- c) With the damaged area cleaned and the adjoining lining wet, mortar shall be spread evenly over the area to be patched in the lining thickness of the surrounding cement liner. After the lining has become firm and adheres well to the surface, it shall finish with a wet paint brush or similar soft bristle brush;
- d) The repaired lining shall be kept moist by tying canvas or wet burlap over the ends of the pipe or fitting for at least 24 hours. As an alternative the repaired lining may be seal coated with a cut back type of asphaltic seal coating. This must be sprayed or brushed on within 5 to 30 minutes after lining.

The repair cement shall comply with Section E.3.10.3.11 "Cement Mortar Internal Lining". Mortar for lining shall not be used after it has been mixed for more than 1 hour. Too rapid loss of moisture from fresh linings due to hot weather or high wind shall be prevented by appropriate curing measures.

E.3.10.10.4 Cold Caulking Compound

Cold caulking compound shall be asbestos free and special cement based material from an approved Manufacturer. The compound shall be suitable for use with water to set to form a hard solid capable of resisting hydraulic pressure immediately. It shall withstand thermal expansion and contraction, vibration and deflection normally associated with pipework applications. The compound shall be applied and cured in accordance with the Manufacturer's instructions.

E.3.10.11 Coated Pipe Handling, Storage and Loading Requirements

Pipe shall be stored, handled and transported in a manner to prevent damage to the pipe walls, bevelled ends and the coating.

Storage racks shall be so designed as to protect the coated pipe from standing water, direct soil contact, and sharp or hard objects that might damage the coating.

The coated pipe shall be shipped using sufficient and proper dunnage to adequately protect the pipe and coating.

E.3.11 Pipeline Appurtenances

E.3.11.1 Flange Connections

Wherever pipes and fittings are connected by flanges, the following standards apply:

- ISO 7005-1 Pipe flanges — Part 1: Steel flanges for industrial and general service piping systems
- EN 1092 Flanges and their joints - Circular flanges for pipes, valves, fittings and accessories, PN designated
- EN 1514 Flanges and their joints - Dimensions of gaskets for PN-designated flanges

E.3.11.2 Fastenings

All bolts, nuts and washers necessary for assembly shall be supplied together with the equipment. The Contractor shall supply an extra 2 % of this assembly material as reserve. The cost of the assembly material + reserve shall be included in the unit price of pipes and fittings.

Bolts and nuts shall comply as a minimum with the requirements of EN ISO 4016 : 2000 and EN ISO 4034 : 2000, grade 4.6. Washers shall comply with EN ISO 7091.

The dimensions of bolts, nuts and washers used for flanged connections shall be in accordance with the flange dimensions. For flanged connections above ground or in chambers, bolts, nuts and washers shall be of stainless steel. All buried flange connections shall be made of hot-dip galvanised steel.

Bolts, nuts and washers and other demountable fastenings of all galvanised parts and also aluminium alloy parts shall be in stainless steel to the appropriate standard. P.T.F.E. washers shall be fitted beneath bolt-head and washer when fastening galvanised and aluminium alloy parts.

Fastenings, except high tensile, of all ferrous parts shall be steel prepared and galvanised to or sheradised to the relevant standards, primed and painted in accordance with location.

Unless specifically approved and required for superior protection, electro-galvanising, nickel, cadmium or any other plating process, except chromium plating, will not be acceptable, and shall not be offered.

E.3.11.3 Contact Corrosion

See section E.2.10.

E.3.11.4 Dismantling Joints

Dismantling joints shall be provided according to ISO 7005 and/or EN 1092-1 or equivalent standard or flange adapters as indicated on drawings or directed by the Engineer. Flanges shall comply with ISO 7005 and/or EN 1092-2, PN 10/16.

If not otherwise directed, body and glands of steel welded dismantling pieces shall be of pressure class PN 16 with bolts and nuts of stainless steel.

Surface protection shall be of one primer coat and two finish coats of solvent based two component epoxy resin. PE-sleeves for application by shrinkage and epoxy paint shall be provided for field-coating and wrapping after installation.

Rubber sealing rings for drinking water application shall be made of Ethylene Propylene Diene Monomer (EPDM).

Rubber sealing rings for wastewater application made of perbunan (NBR) material; nitrite rubber or equivalent quality material shall be used.

E.3.11.5 Flexible Couplings and Flanged Adaptors

Flexible couplings and flanged adaptors shall be suitable for making a watertight flexible connection.

Surface protection shall be of one primer coat and two finish coats of solvent based two component epoxy resin. PE-sleeves for application by shrinkage and epoxy paint shall be provided for field-coating and wrapping after installation.

All mechanical couplings shall be of appropriate internal diameter, shall allow a joint deflection of up to 4° in any direction and longitudinal movements up to 9 mm. and shall be capable of withstanding the maximum working test pressure specified for the pipes they are to connect.

Flanged adaptors shall be capable of providing half of the flexibility of the couplings. Sliding action shall not provide the horizontal movement. It shall occur by deforming of the sealing rings.

All mechanical couplings and flanged adaptors shall be supplied complete with all necessary coupling rings, nuts, bolts, washers and rubber rings.

Wedge joint rings shall comply with ISO 228-1 and/or EN 681-1 or ISO 228-1 and/or EN 681-2 and shall be made of nitrile rubber, ethylene propylene rubber or other approved materials. The sealing shall be resistant against corrosive water and wastewater.

E.3.12 Tees and Wyes

Tees, crosses, couplings, Y-bends or other fittings that provide means of dividing or uniting flow in pipelines shall be factory made and shall comply with the respective standards. These fittings may be connected to pipes by welding. For connection of all kind of valves and return flow preventer, welding neck flanges shall be applied if the nominal diameter of the pipe is greater or equal 150 mm.

E.4. Inspection and Testing of Pipes and Fittings

E.4.1 Testing at Place of Manufacture

Prior to shipment, all material, pipes, fittings and pipeline appurtenances, shall be tested at the place of manufacture in accordance with the approved supplier's / manufacturer's quality assurance system, applicable standards and recognised best business practice. The same applies for the Contractor for his part of supplies, as applicable.

The Contractor shall submit a certificate from the manufacturer certifying that all items have successfully passed the relevant tests prescribed by the respective Standard Specifications. Copies of current authenticated test results in accordance with the manufacturing standard shall be submitted.

Any or all materials and manufactured articles supplied by the Contractor shall, if so required by the Engineer, be tested in advance at the Contractor's expense in accordance with the tests specified in the applicable standards. The Contractor shall arrange for a co-operation with a certified testing lab for the needed testing (third party control).

Mill testing of sewerage pipes shall include one sample of 3 pipes for every 500 m.

E.4.2 Third Party Control

The Contractor shall at his own expense provide a recognized, independent third party control to ensure that the pipes, fittings and other appurtenances are all manufactured in accordance with their respective standards and who shall, among other duties and obligations, testify that they have witnessed all mill tests prescribed by the relative standards and that the material manufactured fulfil in every respect the requirements of the Contract and who shall check the materials in respect of proper packing and certify the Bill of Loading.

Before signing the Contract, the Contractor shall inform the Employer of the name of the control party he intends to engage, and obtain the Employers approval.

E.4.3 Testing of Sewers

The testing of sewers shall include:

- a) tests for straightness and obstructions;
- b) checks on infiltration, and

c) tests for water tightness in accordance to Section E.4.4.

Repair and making good of defaults observed after testing includes, as directed by the Engineer, the correction of alignments and levels and the properly fixing of any two pipes.

Brushing, grouting, cementing or concreting of pipes is not allowed, neither be-fore nor after running the tests. All necessary repairs, re- testing and replacement ordered by the Engineer shall be at the Contractor's expense.

E.4.3.1 Tests for Straightness and Obstructions

Tests for straightness and obstructions will be carried out by mean of visual inspection and/or CCTV survey in accordance to Section Error! Reference source not found. .

Visual tests for linearity and freedom from obstructions shall be carried out after completion of the works and be performed by means of a lamp and mirror. Invert levels of the sewers and inspection chambers shall be tested and verified with levelling instruments.

Carrying out visual checks, the Contractor shall ensure that no unprotected lights are used in existing sewers and manholes or in any new sewers and pipelines in which risks of explosion may be given due to the presence of gases.

If the linearity of a sewer line between two manholes is not given, the Engineer may order to dismantle and relay the pipe or to arrange for an additional manhole at the bending ensuring the linearity between two neighbouring manholes.

E.4.3.2 Checks on Infiltrations

Infiltration checks shall be performed when backfilling is completed and all inlets to the length of sewers under testing have been effectively sealed. For sewers, not exceeding 500 mm nominal diameter, the infiltration rate shall be below 0,05 l/h per 100 linear meters and per mm of nominal bore.

Manholes and inspection chambers will be visually inspected for water tightness against infiltration after backfilling has been completed and groundwater table is at its highest level. Under these conditions no visible infiltration flow shall be admitted.

E.4.4 Water Tightness Testing of Pipelines

E.4.4.1 General

All pipes have to be tested. The tests have to be performed before backfilling of the trenches. Before pipe testing, the trench must be filled with the prescribed granulation of sand to the height of the superstructure above the pipe (30 cm), leaving the joints uncovered so as to prevent the pipeline from moving whilst leaving the joints accessible. Before testing any pipeline, the Contractor shall ensure that it is anchored adequately and that thrusts from bends, branch outlets or from the pipeline ends are transmitted to solid ground, overlay or to a suitable temporary anchorage. If necessary, pipe stabilisation blocks must be constructed before testing. On roads with heavy traffic flow, the backfilling at joints may take place before testing if the Engineer so allows in writing.

The Contractor shall provide labour, install and work the test pump, pressure gauges and all other equipment required for the test and he shall fill the pipes with water and subsequently empty them after the test, all to the approval of the Engineer. Water drained from the pipes shall be discharged in a way that does not affect the stability of the Works or adjacent structures.

The Contractor shall be deemed to have allowed for all expenses in connection with pipe testing.

Before any water tightness test at pressure and non-pressure pipelines commences, the pipelines shall be cleaned by flushing, pigging or swapping. All flushing, pigging and swabbing shall be included in the unit prices for pipe

installation and repetitions of the procedure shall be entirely at the Contractor's expense. It is therefore in the Contractor's interest to maintain the cleanliness of the pipe during and after installation.

The ends of pipes under test shall be closed by means of plugs, caps or blank flanges with anchors all provided by the Contractor. Valves must not be used for this purpose. All scour valves and air valves shall be replaced by blank flanges before the commencement of the tests.

Potable water shall be used for the cleansing, testing and swabbing of water supply pipelines unless otherwise directed by the Engineer. Stand pipes for extracting water from the public supply system shall be in accordance with the requirements of the supply authority. As a minimum a check valve system shall be provided between the public supply and the item being filled to prevent the possibility of backflow.

After laying, jointing and anchoring the pipe shall be slowly and carefully filled with water so as to avoid water hammer and all air shall be released through the upper pipe end or in case of an intermediate high point by installing a service connection with a tap. Pipes internally lined with cement shall be allowed to stand full for at least 24 hours before testing to saturate the lining with water.

The test pressure shall be applied by means of a manually or motor operated test pump connected to the pipe and two parallel installed pressure gauges calibrated at an approved testing laboratory.

All joints, pipe foundations and the like shall be inspected during testing and pressure shall be maintained until such inspections are completed or as specified by EN 805 for the duration of testing, which ever lasts longer.

Should leakage of water occur at the joints, the joint shall be reassembled to eliminate such leakage or, should this not prove possible, the Contractor shall supply and assemble new joints at his own expense. Should any pipe or joint burst or should water leak through the body of a pipe or joint the Contractor shall forthwith remove the faulty pipe or joint and replace them with new at his own expense. No makeshift repairs or application of patching compounds shall be permitted. In all the above cases the length under test shall be re-tested as above described and the process repeated, if necessary, until the pipeline satisfactorily withstands the prescribed test.

In the event that pressure loss encountered during test is higher than acceptable and/or any visible leak occurs or any foundation or puddle flange is found to have moved or cracked or appears damaged in any way, or if any pipe barrel or flange shows deformation, the test shall be declared as being unsuccessful.

With the approval of the Engineer pipelines with an internal diameter greater than 100 cm may alternatively be tested by a combination of visual inspection from the inside and the use of equipment designed to test the tightness of individual joints. This test, however, does not relieve the Contractor of his obligation to guarantee watertightness of pipelines. Furthermore, individual joints have to be testable (i.e. double gasket with spacing and devices to connect test equipment).

Should the losses in any line tested exceed the permissible leakage by more than 5 %, the Contractor shall determine the cause of the failure and shall locate, excavate and repair any damage or leakage sustained by the pipeline before or during the tests, and after repairing and making good any leaks, carry out further tests to prove evidence of the permissible leakage rate. The cost of such repair work, including (but not limited to) additional excavation and back-filling; repair or replacement of pipes; and the abortive test shall be borne by the Contractor.

No visible sign of leakage will be accepted. If a leak occurs in the pipeline it shall be located and shall be made good by the Contractor at his own expense before restarting the test.

If, during iterated testing the loss rate fails the permissible leakage by more than 5 %, the line shall be dismantled and reconstructed with new pipes at the Contractor's expense. The above procedure shall apply also for lines and house

connections which are to be tested after backfilling, whereby a tolerance of 15 % from the permissible leakage rate infiltration shall be allowed.

If the calculated leakage rate is within the allowable leakage rate, the test water shall be transferred to the next section of the pipeline to be tested or disposed of as approved by the Engineer.

E.4.4.2 Test Report (Record)

A test report (record) shall be prepared in respect of each and every test performed. The test report shall contain as a minimum the following data:

- Number and date of the test;
- Description of the stretch tested with unambiguous indication of the extremities of the stretch;
- Sketch showing in the order of laying, the number and the characteristics of the pipes, the fittings the specials and other apparatus incorporated in the stretch;
- Duration of the test, test pressure, results obtained;
- Decisions relative to possible repair works and conclusions.

The test record shall be signed by the Contractor and the Engineer.

The record shall be signed by the Engineer and the Contractor and the chart of the test attached. This report (record) shall be produced when applying for Taking Over of any particular area. This documentation shall be prepared by Contractor and comprise all relevant information.

E.4.4.3 Pressure Testing of Mains

Pressure pipelines (together with all specials and valves incorporated) shall be tested with water in accordance with EN 805.

The Contractor shall provide all test rigs, temporary blind flanges, caps, plugs, pressure gauges, pipe connection cocks, Struts, Thrust blocks, pressure raising equipment, pressure recording instruments and all other necessary equipment to satisfactorily carry out the tests as specified in this Requirement. The Contractor shall further supply all labour and supervision needed for the performance of the tests and recording the results.

All gauges and equipment are to be submitted for approval to the Engineer. All test gauges shall be dead weight tested and proved at the commencement of use and at regular intervals thereafter as required by the Engineer. A pressure recorder shall be installed to provide a continuous record of the test and the chart submitted as part of the documentation for each pressure test performed.

The Contractor shall submit a systematic procedure for testing and a method of filling and draining all mains and pipework for approval to the Engineer. The pressure drop method shall be applicable as set forth by ISO 24516 and/or EN 805.

Prior to testing any pressure pipeline the Contractor shall submit for the Engineer's approval details of all temporary thrust blocks. These details shall be submitted with sufficient calculations to demonstrate that the thrust blocks will resist the specified test pressure. The

The Contractor shall supply all of the water required for the tests. Water may originate from the existing distribution system through direct connections or through hydrants, where permitted by the Employer in writing and approved by the Engineer or from Contractor's tanker trucks. Before start of test, air must be completely removed from the test section as its presence falsifies the test results.

Pipes shall be filled with potable water and tested in sections of convenient lengths, which must not exceed 500 meters. Where pipes are laid with steep gradients the length of pipes tested at any one time shall be as directed by the Engineer.

The Contractor shall perform the hydrostatic test, on all complete piping, prior to field coating of welds and fittings and prior to backfilling of the joints.

Before testing, valves shall be checked and sealed, the sections of main filled with water and the air released. After having been filled, pipelines shall be left under operating pressure for the period specified in ISO 24516 and/or EN 805, so as to achieve conditions as stable as possible for testing.

The Contractor shall provide and fit any test heads required, and the Engineer shall be informed in time to make a final check of each section to be tested before test heads are connected. The Contractor is obliged to provide all the necessary materials and equipment on the test heads or on pipeline routes, in accordance with the requirements for filling and venting during Site testing. Fill and vent points in the pipe shall be closed afterwards. Thrust blocks shall be provided and removed after testing. Tests shall not be performed against valves but against blank flanges and test heads exclusively. Pressure testing against closed valves or air valves will not be permitted.

Calibrated manometers of class 0,6 Ø 160 mm shall be used for testing and be placed at the lower end of the test section. Gauges used for testing pressure pipelines shall be capable of reading increments of 0,1 m head. The Contractor shall be responsible for the independent calibration of the gauge prior to commencement of testing.

System Test Pressure (STP), test duration and criteria for successful test shall be as indicated in the following table. The test pressure always applies to the lowest point of a test section.

Pipe material	Test Pressure (STP)	Test Duration	Successful test criteria
Ductile cast iron pipelines	PN 10: 1,5 MPa PN 16: 2,1 MPa	DN ≤ 200: 3 hours 200 < DN ≤ 400: 6 hours DN > 400: 12 hours	Max pressure drop for: PN 10: 10 kPa PN 16: 15 kPa
Steel pipelines	PN 10: 1,5 MPa PN 16: 2,1 MPa	DN ≤ 200: 3 hours 200 < DN ≤ 400: 6 hours 400 < DN ≤ 700: 12 hours DN > 700: 24 hours	Max pressure drop for: PN 10: 10 kPa PN 16: 15 kPa
Reinforced concrete pipes	PN < 0,25 MPa: 1,4 x PN PN > 0,25 MPa: PN + 0,1 MPa	DN ≤ 700: 12 hours DN > 700: 18 hours	Average replaced water losses during the first 6 hours: less than 0,15 l/m ² /hour (wetted inner surface)

Pipe material	Test Pressure (STP)	Test Duration	Successful test criteria
Prestressed concrete pipes	PN < 1,00 MPa: 1,5 x PN PN > 1,00 MPa: PN + 0,5 MPa		Average replaced water losses during the first 6 hours: less than 0,02 l/m ² /hour (wetted inner surface)
PVC, HDPE pipes	Test according to EN 805 and DVGW W 400-2		
GRP pipes	Test method of EN 805 shall be applied		

E.4.4.4 Pressure Testing of Plumbing Systems

The hydraulic test pressure of plumbing systems shall be 1,5 times the maximum working pressure for a period of 30 minutes. In addition to the above the equipment shall be inspected and tested after erection. On completion all plumbing systems shall be flushed out with clean water and then subjected to a hydraulic test of 1,5 times the working pressure for a period of not less than 30 minutes. All welds shall be hammer tested and remain firm. A normal working test shall then be carried out with the plant operating temperature.

During this test all necessary adjustments and regulations of valves shall be effected. Installations or sections thereof which will be embedded in the structure or concealed in permanently sealed ducts, trenches etc. shall, in addition to the

above specified tests be individually tested as they are laid before being embedded or concealed. All pressure tests specified above shall be carried out before the application of thermal insulation.

E.4.4.5 Water Tightness Testing of Gravity Pipes and Mains

E.4.4.5.1 General Requirements

Testing the water tightness of the gravity pipelines and chambers shall be in compliance with EN 1610. All costs related to these test are including in the sewer pipe laying unit rates.

Gravity pipelines shall preferably be tested with water. Air tests are subject to the approval of the Engineer.

Two types of water testing shall be implemented:

- Pipeline testing;
- Chamber testing.

Combined testing of pipelines and chamber(s) is not allowed.

The tests shall be implemented after laying the pipelines and chambers, before any concrete surround or backfill is placed, other than such as may be necessary for structural stability whilst under test.

The pipelines shall be tested in lengths applicable to the construction activities and in accordance with the programme.

A further test shall be carried out when any concrete works have been completed and when backfill has been placed and compacted to a depth of 300 mm above the crown of the pipeline

The test schedule shall be approved by the Engineer.

E.4.4.5.2 Pipeline Testing

All lengths of sewers shall be tested for water tightness by means of hydrostatic testing. Hydrostatic testing shall be applied after partial backfilling leaving the joints exposed. Testing shall be carried out from manhole to manhole. Short branch laterals connected to the sewer may be tested as one system with the sewer. Long branches and manholes shall be separately tested.

All watertightness tests shall be in accordance with EN 1610, construction and testing of sewer pipes. In addition to EN 1610, all gravity sewer pipes (including iron or steel pipes, if any, or special parts on sections) can be tested before and after backfilling. The test procedures shall be performed according to (EN 476; EN 681, EN 921). The test prior to backfilling is called the initial visual test. Visual test includes direction control, longitudinal level drop, inspection of joints, etc. Backfilling shall not be done until the test is successful. However, the final test is important for the acceptance of works. Sewer lines shall be tested lengthwise according to the instructions of the Engineer. The Engineer has the right to choose water or air tests depending on the type and conditions of work.

The tests shall be performed in the presence of the Engineer according to his instructions and to his satisfaction. A record for each test (successful or not), with all the information required by the Engineer, should be made by the Contractor. The Contractor and Engineer shall sign the record and a copy of the record will be delivered to the Engineer immediately after the test is completed. Lines shall be tested for lengths between manholes or for shorter lengths approved by the Engineer, and in all cases the tests shall be performed in the presence of the Engineer. All lengths of outlet and sewer pipes, all manholes and inspection chambers shall be checked for flatness, obstruction and groundwater infiltration.

Each sewer line and manhole to be tested shall comply with the following conditions: (i) Sewer lines shall be completely clean and dry and joints open (uncovered) (ii) The groundwater level in the trenches shall be kept as low as possible and in any case below the pipes and joints.

All lengths of damaged sewer lines shall be immediately put in proper and satisfactory condition, by repairing or if necessary re-installing the entire damaged length and shall be tested again and the procedure will be repeated until satisfactory results are obtained, all at the expense of the Contractor. Testing costs and all costs incurred due to repair or replacement of sewer lines (including removal of damaged and adjacent pipes or joints and preparation, laying and joining of new pipes and joints where necessary and all associated costs) shall be fully borne by the Contractor. Water used for watertightness testing must be supplied and disposed of by the Contractor. It is not allowed to dispose of the water used for testing in the sanitary sewage system. In relation to the above-mentioned retesting, the Engineer may order retesting of certain lines by one of the approved methods. If the retesting shows that the lines are no longer able to withstand the test, the Engineer shall immediately request that the damage be repaired and the sewer line retested until satisfactory results are obtained for all costs incurred, including retesting costs, which shall be borne by the Contractor.

The Contractor shall provide a fixed and operating compression pump, manometers, air balloons, air filter devices and other devices required for Engineer approval and he shall fill the pipe with water and empty it after the test. Water drained from the pipe shall be discharged in a way that shall not affect the stability of the works and the adjacent structure. All water will be supplied and disposed of at the expense of the Contractor. Sealing of all test joints in manholes and sewers should be provided. The tested element shall be sealed with adequate pipe plugs. It includes pipes connections to the tested element.

The hydrostatic testing shall be carried out as follows:

- a) After completing the installation and covering of a sewer line or a section of the line, hydraulic testing of the line shall be performed, when directed by the Engineer. The test pressure shall be 1,0 m head of water at the highest point of the section under consideration. The length of each section to be tested shall not exceed 100 m and the pressure at the lowest point of the section shall not exceed 5,0 m head of water;
- b) At the upper end of the sewer (highest point of the test section) a transparent part of the pipe of plastic or glass (glass gauge) shall be connected to the sealing plug to enable the observation of the water level during the test. The level observation pipe should have an inner diameter of approx. 35-50 mm and a length of min. 3.0 m, shall be provided with a centimetre marking starting as of 1,0 m above the top of the sewer. An air vent and a cock should be installed at the same end as to allow for the release of air during the filling of water for testing;
- c) The pipe shall be filled with water for a period of minimum 2 hours and maximum 24 hours before testing in order to allow for an adequate soaking period and the complete release of air. The water level shall be kept at the mark of the gauge glass during the entire soaking period. The hydrostatic test shall be carried out immediately after the soaking period;
- d) The leakage of the pipe is defined as the quantity of water which must be supplied to the pipe during 30 minutes to maintain the specified water level. The additional quantity of water filled into the pipe shall be measured with an accuracy of 0,1 litres. The losses shall be replaced steadily;
- e) The sewer will be accepted in respect of water tightness if the water loss after 30 minutes is not higher than 0,15 l/m² of pipe surface in contact with water (wetted inner surface) and if no other leakage is visible.

E.4.4.5.3 Chamber Testing

All manholes must be made watertight, and the Contractor shall take steps to ensure that this is done. Generally, the manholes shall be tested before backfilling the surrounding excavations so that all necessary repairs can be carried out

before backfilling. All such tests shall be borne by the Contractor and in accordance with instructions that the Engineer may issue.

The manholes shall be tested by closing all the openings on the pipes with watertight shutters (balloons) and then they shall slowly, in stages, fill with water. In the event of a reduction in water levels, the causes and sources of water leakage will be identified and repaired to ensure that the manhole is completely watertight.

Testing of external water infiltration through manholes can be performed when shallow groundwater (water infiltration) is at least 30 cm higher than the edge of the highest pipe connected to the manhole. This test is performed when the backfill is complete, allowing the water infiltrations to reach their normal level, and observing the inner surface of the manhole. In this case, water infiltration inside the manhole is not allowed. Testing is carried out on all newly built manholes on the main and secondary collectors, as well as connection manholes of house connections. The pipe connections of the tested chamber shall be sealed with adequate pipe plugs. The chamber shall be filled with water up to 10 cm below cover level.

The volume of water loss and the related water pressure shall be measured and record during 30 minutes with interval of 0,1 l (i.e. accuracy).

The test shall be considered as successful if the water loss after 30 minutes is not higher than 0,40 l/m² of the chamber surface in contact with water.

E.4.4.5.4 Air Test for Sewer Pipelines

The air test is recommended for larger profile pipelines due to the shorter duration and water savings. All ends, branches, inspection manholes for visual control and other openings shall be closed with watertight shutters prepared by the Contractor. One of the closed openings shall have an air supply pipe on which a manometer shall be placed. When using low pressure, an open pipe gauge gives the best results and shall therefore be used. Air shall be blown or pumped to the length within the test until the equivalent of the specified pressure is displayed on the manometer. The time required to obtain the specified pressure reduction shall be measured.

Pipelines to be air tested shall have air pumped into the length under test until a pressure equivalent to 100 mm of water is indicated on a U tube gauge connected to the system. The pipeline shall be accepted if the air pressure does not fall below 75 mm water gauge after a period of five minutes without further pumping.

A successful test shall meet the following requirements:

- 1) The pressure will rise to 1.1 m of water pillar (WP) at the highest point in the water. When the pressure drops to 1.0 m WP, the time measurement starts.
- 2) The time during which the pressure drop is 0.5 m WP will not be less than the amount below:

Inner diameter:												
(mm)	200	300	400	500	600	700	800	900	1000	1200	1400	1800
Time:												
(min)	2	3	5	7	9	11	13	15	17	20	23	26

Measures must be taken to ensure that the air pressure in the pipes never exceeds 3 m WP. If a compressor with higher pressure is used, the pressure reduction valve will be set to 0.3 bar.

E.5. Disinfection

E.5.1 General

The disinfections shall be carried out in accordance with the following procedure. This procedure shall be carried out before being commissioned.

The entire disinfection procedure requires documentation in written form and confirmation by the Engineer.

The Contractor shall include all costs of labour, transport, materials, equipment, chemicals and water necessary for the satisfactory completion of the cleansing and sterilisation operations in his prices. The Contractor shall be responsible to maintain the quality of the works from disinfection to commissioning at his costs.

Disinfection of water supply facilities shall be carried out in accordance with EN 805.

EN 805 recommends several disinfectants. The disinfection agent can be Sodium hypochlorite NaOCl or Calcium chlorite $\text{Ca}(\text{ClO}_2)_2$. The disinfectant may be selected by the Contractor and submitted to the Engineer for approval together with the method of application. It is recommended to use a hypochlorite solution; the process for the hypochlorite solution is given hereinafter.

The concentration of the disinfection's agent per litre in the water must be between 35 and 50 mg/l. The duration of disinfection shall not remain under 12 hours. After that period the facilities shall be flushed with potable water.

Any effluent from the disinfectant shall be duly neutralised and disposed in compliance with local regulations.

The entire disinfection procedure requires documentation in written form and confirmation by the Engineer.

The Contractor shall be responsible to maintain the quality of the works from disinfection to commissioning at his costs.

E.5.2 Test Procedure

Before the pipeline is placed in service, and before issue of the Provisional Acceptance Certificate by the Employer/ENGINEER, all pipelines shall be disinfected and flushed as per EN 80, ANSI/AWWA C651 or as directed by the Employer/ENGINEER.

The pipelines shall normally be disinfected at the same time as the hydrostatic tests performed or as directed by the Employer/ENGINEER.

Before the CONTRACTOR intends to undertake disinfecting/flushing of all or part of the pipelines, the CONTRACTOR shall submit a detailed proposal for the work showing the quantity of water required. This quantity of water may be made available by the Employer from the nearest available source free of charge and shall remain the property of the Employer.

The chlorine dose shall be obtained from a chloral solution or other suitable solution to be approved by the Employer/ENGINEER. Samples taken from the pipeline during disinfection at locations directed by the Employer/ENGINEER shall be checked by a suitable comparator in order to ensure that the sterilising liquid is present throughout the system and at sufficient strength.

At the end of the 24 hour period at operating pressure the chlorine concentration shall be checked. If there is less than 1 mg/l of free available chlorine in the water, more chlorine solution shall be introduced and left for a further 24 hour period after which the free available chlorine concentration shall be checked again. This procedure shall be repeated as necessary until the free available chlorine taken after 24 hours exceeds 1 mg/l for all samples taken from the area of pipeline under test. The hydrostatic test shall not be commenced until this requirement is satisfied.

Should the hydrostatic test fail and repair work involve emptying the pipeline then the disinfection and subsequent testing procedures shall be repeated in full at the CONTRACTOR's own expense.

After all hydrostatic testing has been completed and section of pipeline is ready for handing over in all other respects including the installation of house connection saddles and ferrules where appropriate, the new pipeline shall be flushed out by potable water from the existing mains to which the new pipeline or network is or will be connected. Flushing entry and exit points shall be designed to allow a minimum of 1.0m/s water velocity in the main pipeline or as directed by the Employer/ENGINEER. The quantity of flushing water shall be calculated as the equivalent to 3 times the volume of the pipeline to be flushed unless directed otherwise.

It shall be a condition that the water in the existing network at the point of extraction shall register a minimum of 0.4 mg/l of free available chlorine when tested with a site comparator prior to any approval being given to commence flushing. If a reading of less than this is obtained the Employer/ENGINEER shall be informed and the CONTRACTOR instructed accordingly. Once flushed, the water in the new pipelines shall be allowed to stand for a further 24 hours. Samples shall then be taken from locations directed by the Employer/ENGINEER and immediately submitted for chemical and bacteriological testing at the approved laboratories.

The pipeline shall not be considered acceptable until faecal coliforms are undetectable in a 100 ml sample, the bacterial count is within approved limits, the recorded total chlorine content is a minimum of 0.2 mg/l and the pH is within acceptable limits.

The pH value of water contained in newly constructed cement mortar lined pipes can be significantly higher than acceptable limits. The CONTRACTOR should thus make allowance for additional flushing if required, in order to reduce the pH to a value which is acceptable.

If the tests show that a satisfactory drinking water standard has not been achieved, the CONTRACTOR shall repeat the disinfection procedure, tests and flushing, all at his own expense, until these requirements are met.

The CONTRACTOR is responsible for making himself fully aware of the statutory requirements for achieving acceptance of bacteriological and chemical standards of the water in the pipelines under construction.

Flushing water shall be discharged via temporary discharge lines to the surrounding open desert area or into the existing storm water system or, if feasible, into road tankers. Discharging of flushing water into the existing storm water system shall be subject to approval of the relevant Authorities.

Any temporary connections required for flushing shall be at the CONTRACTOR's cost, and shall be included in his unit rates for construction work. All other materials, equipment and labour required for the disinfection, flushing operation and discharge of water shall also be furnished by the CONTRACTOR and included in his construction rates.

E.6. Hydraulic Design of Water Supply Pipelines

E.6.1 Scope and Obligation of the Contractor

This Clause applies to every water supply pipeline reinstated, replaced, extended or newly laid under the Contract, whether a transmission main, a rising main from a well or pumping station, a distribution main or a sub-network, and to the appurtenances on those lines.

The Contractor shall not assume that the replacement of a damaged pipe by a pipe of the same diameter as the pipe destroyed is sufficient. Before any pipe is ordered, the Contractor shall carry out, and submit to the Engineer for approval, a hydraulic design check of each line to be reinstated or laid, establishing the design flow, the head loss over

the line, the residual pressure at the critical node and the pressure class required, and confirming that the diameter proposed delivers the required level of service.

Where the Bills of Quantities describe pipes as “as existing (SLWE approved)”, or state a diameter or material, that description fixes the basis on which the item is priced and measured; it does not relieve the Contractor of the obligation under this Clause, nor does it constitute a representation by the Employer that the pre-existing diameter is hydraulically sufficient.

This Clause does not require the Contractor to redesign the water supply system of a village as a whole. The obligation is limited to the lines forming part of the Works, together with the hydraulic interface between those lines and the existing network, storage and pumping installations to which they connect.

E.6.2 Standards

The hydraulic design shall be carried out in accordance with EN 805 “Water supply — Requirements for systems and components outside buildings”, and with the following so far as they are applicable:

- EN 1295-1 and Clause E.1 of these Specifications, for the static calculation of pipelines;
- EN 12201 and ISO 4427 for polyethylene pipes and fittings, EN 545 for ductile iron, and EN 10224 and EN 10217 for steel;
- the Lebanese Standard NL 161 for potable water, in respect of materials in contact with water and of water quality on recommissioning;
- the operating practice, service levels and design criteria of the South Lebanon Water Establishment, where these are notified to the Contractor through the Engineer.

Where EN 805 and the instructions of the South Lebanon Water Establishment differ, the Contractor shall refer the matter to the Engineer for decision before proceeding.

E.6.3 Design Data and Assumptions

The Contractor shall obtain, through the Engineer, the data held by the South Lebanon Water Establishment for the village concerned, including the population and number of connections served, the recorded well yields, the storage capacity and operating levels, the recorded length and layout of the network, and the hours of supply in each supply zone. The Contractor shall state in its submission the source and date of every item of data used.

Unless the South Lebanon Water Establishment directs otherwise through the Engineer, the following shall be adopted, and shall be stated expressly in the submission so that the Engineer may confirm or vary them:

Parameter	Value to be adopted unless otherwise directed
Design horizon	20 years from the date of Completion
Design population	The population recorded by the municipality and the South Lebanon Water Establishment at the date of the Contract, adjusted for the returning population confirmed by the municipality, and projected over the design horizon at the rate stated by the Employer
Per capita demand	The service standard of the South Lebanon Water Establishment for the village concerned; where none is notified, 150 litres per head per day, stated as an assumption to be confirmed
Peak day factor	1.3 times the average day demand
Peak hour factor	2.5 times the average hour of the peak day, or as derived from the actual hours of supply where supply is intermittent
Non-revenue water	The figure notified by the South Lebanon Water Establishment; where none is notified, 35 per cent, stated as an assumption to be confirmed
Fire-fighting demand	Not included unless instructed in writing, in which case as instructed
Intermittent supply	Where supply is for a limited number of hours per day, the design flow shall be the demand of the day compressed into the actual hours of supply, and this shall be stated

Where the Contractor considers that a value adopted above is not appropriate to the village concerned, it shall say so in its submission and propose an alternative with its justification.

E.6.4 Hydraulic Criteria

The following criteria shall be satisfied at the design condition. Where any criterion cannot be satisfied without a change of diameter, Clause E.6.7 applies.

Criterion	Requirement
Minimum residual pressure	Not less than 15 m of water above ground level at the connection point of the most unfavourable property served, at the peak hour of the peak day
Maximum static pressure	Not more than 60 m of water in a distribution zone; in no case greater than the nominal pressure rating of the pipe less the allowance for surge established under Clause E.6.6
Design pressure and MDP	Design pressure, maximum design pressure and system test pressure to be established in accordance with EN 805 and stated for every reach
Velocity — distribution mains	0.6 to 1.5 m/s at the peak hour; 2.0 m/s shall not be exceeded
Velocity — transmission and rising mains	0.8 to 2.0 m/s; the economic velocity shall be demonstrated where the line exceeds 500 m
Minimum velocity	Not less than 0.3 m/s shall be achieved in each main at least once in every 24 hours, so that sediment does not accumulate; where this cannot be achieved, a washout and a flushing regime shall be provided and recorded in the operation and maintenance manual
Minimum diameter	No distribution main smaller than DN 63 for polyethylene or DN 50 for ductile iron; no house connection smaller than 25 mm outside diameter
Head loss	Darcy–Weisbach with the Colebrook–White equation, or Hazen–Williams where the Engineer accepts it; the coefficient adopted shall be stated for every reach
Roughness — new pipes	$k = 0.03$ mm for polyethylene and PVC; $k = 0.10$ mm for cement-mortar-lined ductile iron; or $C = 150$ and $C = 130$ respectively where Hazen–Williams is used
Roughness — existing pipes retained in the hydraulic circuit	$k = 0.50$ mm, or $C = 110$, unless a lower value is demonstrated by field measurement
Minor losses	Valves, bends, tees, meters and connections to be accounted for, either by equivalent lengths or by loss coefficients, and the basis stated
Appurtenances	Air valves at every high point and at intervals not exceeding 500 m on rising ground; washouts at every low point and at the end of every main; isolating valves so that no more than 30 connections are taken out of supply by a single closure

E.6.5 Analysis and Modelling

The Contractor shall prepare a hydraulic model of each line forming part of the Works together with the part of the existing network, storage and pumping installation with which it interacts. The model shall be built in EPANET or in an equivalent established hydraulic solver acceptable to the Engineer, and the model files shall be submitted with the design report.

The following conditions shall be analysed as a minimum:

- peak hour of the peak day, with the reservoir at its minimum operating level;
- average day, for the verification of velocities and of the operation of the pumping plant;
- minimum night flow, for the verification of maximum pressures;
- the filling condition, where the line delivers to storage, for the verification of the duty of the pump set under Clause G.42;
- the transient conditions required by Clause E.6.6.

After reinstatement and before the pressure test is accepted, the Contractor shall take field measurements of pressure at not fewer than three points in each village, and of flow at the outlet of the well or reservoir concerned, and shall reconcile them with the model. Where the measured and modelled values differ by more than 15 per cent, the Contractor shall establish the reason and report it to the Engineer.

E.6.6 Surge and Transient Analysis

A transient analysis shall be carried out in accordance with EN 805 and Clause G.38 for every rising main, for every transmission main, and for any pumped line exceeding 500 m in length or served by a pump set of rated output exceeding 15 kW. The analysis shall cover pump start, normal shut-down, power failure with the pump tripping on full duty, and the rapid closure of a valve.

The pressure envelope established by the analysis shall satisfy the following: the maximum transient pressure shall not exceed the nominal pressure rating of the pipe and of the fittings at any point; and the minimum transient pressure shall not fall below minus 5 m of water, and in no case below the vapour pressure of water at the operating temperature. Where these limits cannot be satisfied, surge protection shall be provided in accordance with Clause G.38, and its sizing shall follow from the analysis and not from a nominal allowance.

The particular attention of the Contractor is drawn to the transmission main at Zawtar al-Gharbiyeh, which operates at a high static head; the pressure class of that line, and the protection against surge, shall be established by analysis before any pipe is ordered.

E.6.7 Where the Existing Diameter is Hydraulically Inadequate

Where the hydraulic check establishes that the diameter of the pipe destroyed, or the diameter stated in the Bills of Quantities, cannot deliver the design flow at the residual pressure required by Clause E.6.4, the Contractor shall not order that pipe. It shall report the matter in writing to the Project Manager within seven days of establishing it, enclosing the calculation and stating the diameter, material and pressure class it recommends and the cost consequence.

The Project Manager shall determine the diameter to be installed, in consultation with the South Lebanon Water Establishment and the Employer, and shall instruct the Contractor accordingly. Any resulting change to the Works shall be instructed as a Variation and valued in accordance with the Contract.

Where, conversely, the check establishes that the pre-existing diameter is materially larger than the design requires, the Contractor shall report that also. The diameter shall not be reduced below that stated in the Bills of Quantities without the written agreement of the South Lebanon Water Establishment, since the existing diameter may serve an operational purpose, such as storage within the main, future demand or fire flow, which is not apparent from the hydraulic calculation alone.

E.6.8 Submissions and Approval

The Contractor shall submit the hydraulic design not less than 28 days before the date on which it intends to place an order for pipes for the line concerned. The submission shall comprise:

- a design report stating the scope, the data used and its source, the assumptions adopted under Clause E.6.3 and the criteria applied under Clause E.6.4;
- the demand calculation for each supply zone;
- the hydraulic calculations and the model files, in native format;
- longitudinal profiles of each line showing ground level, pipe level, the hydraulic grade line at the peak hour and the maximum and minimum transient envelopes;
- a schedule, reach by reach, of length, diameter, material, pressure class, design pressure, maximum design pressure and system test pressure;
- schedules of air valves, washouts, isolating valves, thrust blocks and anchor blocks;

- the transient analysis required by Clause E.6.6 and the sizing of any surge protection.

The submission shall be in English. The Engineer may require a summary in Arabic. No pipe shall be ordered, and no trench opened for a line whose design has not been approved. The approval of the Engineer shall not relieve the Contractor of its responsibility for the design submitted.

E.6.9 As-Built Hydraulic Record

On completion, the Contractor shall update the hydraulic model to reflect the lines as constructed, including the measured lengths, the diameters and materials actually installed and the results of the field measurements taken under Clause E.6.5, and shall deliver the updated model, the final design report and the as-built hydraulic grade lines to the South Lebanon Water Establishment through the Engineer, together with the as-built drawings.

Technical Specifications

Well Works and Testing

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F.1. General

F.1.1 Scope of this Part

This Part specifies the works to be executed in and at existing water wells forming part of the Works, and the testing, disinfection and recommissioning of those wells. It covers the withdrawal of existing pumping equipment; the inspection of the well; the cleaning and development of the well where required; the supply, installation and setting of the submersible pump set, rising column, cables and instrumentation; the reconstruction and repair of the well head, sanitary seal and well head chamber; pumping tests; disinfection and water quality verification; and the records to be handed to the South Lebanon Water Establishment.

The drilling or construction of a new well or borehole does not form part of the Works. Should the Employer at any time instruct the construction of a new well, this Part shall be supplemented by specifications for drilling, casing, screening, gravel packing and grouting before that work is put in hand.

This Part is to be read with Part D for the civil works at the well compound, Part E for the pipework from the well head, Part G for the pump set, valves, metering and lifting equipment, Part H for the electrical installation, and Part I where photovoltaic generation serves the well.

F.1.2 Standards

The works of this Part shall comply with the following, and with the other Standards referred to in these Specifications so far as they are applicable:

- ISO 14686, Hydrometric determinations — Pumping tests for water wells — considerations and guidelines;
- AWWA A100, Water Wells;
- AWWA C654, Disinfection of Wells;
- EN 805, for the supply system downstream of the well head, and Clause E.6 of these Specifications;
- the Lebanese Standard NL 161 for potable water, and, where that Standard is silent on a parameter, the WHO Guidelines for Drinking-water Quality;
- the conditions of the groundwater abstraction authorisation held by the South Lebanon Water Establishment for the well concerned, which the Contractor shall obtain through the Engineer and shall observe.

F.1.3 Responsibility of the Contractor

The Contractor shall satisfy itself as to the condition and construction of each well before pricing and before executing any work in it. The records issued with the bidding document are provided for information only, are incomplete for some wells, and shall not be relied upon as a warranty of the condition of the well. Where no record exists for a well, the Contractor shall establish the information required by Clause F.2 by measurement and by the inspection required by Clause F.5.

No work shall be executed in or at a well except by personnel experienced in water well work, under the supervision of a competent person nominated by the Contractor and accepted by the Engineer.

F.2. Information to be Obtained before Work in a Well

Before any equipment is withdrawn from a well, the Contractor shall obtain, through the Engineer, and shall submit to the Engineer on a Well Data Sheet in a form approved by the Engineer, the following information for that well:

- a) the well completion record and the drilling log, including the strata encountered;
- b) the casing and screen schedule, giving for each string the diameter, wall thickness, material, the depths at which it is set, and for the screen the type and slot size;
- c) the depth and extent of the gravel pack and of the grout seal, and the depth of the sanitary seal;
- d) the total drilled depth and the current accessible depth;
- e) the static water level, and the dynamic water level and yield recorded at the last test or in operation, with their dates;
- f) the make, model, rating, stage count and setting depth of the pump set last installed, and the make and size of the rising column and the cable;
- g) the characteristics of the power supply and the rating of the existing panel, drive and protection;
- h) the abstraction authorisation and any limit it places on the rate or the annual volume abstracted.

Where any of the above is not held by the South Lebanon Water Establishment, the Contractor shall establish it by measurement, and shall at least determine the accessible depth by sounding, the internal diameter of the casing, and the static water level, and shall carry out the inspection required by Clause F.5. The Well Data Sheet shall identify every item so determined and shall distinguish it from the information held in the records.

The Well Data Sheet shall be submitted and accepted by the Engineer before any equipment is withdrawn from the well.

F.3. Method Statement

The Contractor shall submit, not less than 21 days before it intends to commence work in a well, a method statement for the Engineer's approval covering, as a minimum:

- the sequence of operations and the programme, and the interface with the water supply continuity arrangements for the village;
- the plant and equipment to be used, including the lifting appliance, and the lift plan required by Clause G.39 and by the environmental and social management requirements of the Contract;
- the arrangements for preventing the dropping of equipment into the well, the clamps and the tool control register required by Clause F.4;
- the arrangements for the hygiene of the well, including the cleaning and disinfection of every item before it is lowered;
- the route and destination of the discharge from development and testing, and the arrangements for settlement, dechlorination and erosion control required by Clause F.11;
- the procedure to be followed in the event that an object is dropped into the well, including the fishing equipment that will be mobilised;
- the arrangements for the measurement, recording and reporting required by Clause F.10.

No work shall be carried out in a well before the method statement for that well has been approved in writing.

F.4. Withdrawal of Existing Equipment

Before any equipment is withdrawn, the Contractor shall record and photograph the arrangement as found, and shall measure and record the setting depth of the pump, the length and condition of the rising column, the condition of the cable and of the clamps, and the position of any dip tube or air line.

Withdrawal shall be carried out with purpose-made clamps and lifting equipment of adequate capacity, properly tested and certified. Improvised clamps, slings passed around the column and the lifting of a string by the cable are prohibited. The well mouth shall be protected against the entry of foreign matter throughout the operation, and shall be securely covered whenever work is suspended, including at the end of every shift.

The Contractor shall maintain a tool control register for each well, in which every item lowered into the well is entered on lowering and signed out on recovery. The register shall be available to the Engineer at all times and shall be reconciled before the well head is finally closed.

Equipment withdrawn from a well remains the property of the Employer. It shall be cleaned, listed and handed to the South Lebanon Water Establishment, or disposed of as the Engineer instructs, and the disposal recorded.

Where an object is dropped into a well, the Contractor shall notify the Engineer immediately and shall not continue other work in that well until the object is recovered. Where the loss arises from the default of the Contractor, the recovery of the object and the making good of any damage to the well shall be at the Contractor's cost.

F.5. Inspection of the Well

The Contractor shall carry out a downhole colour television survey of each well over the full accessible depth, with a camera giving both an axial and a side-scanning view and a continuous depth read-out. The survey shall be carried out after the existing equipment has been withdrawn, and shall be repeated after any cleaning or development carried out under Clause F.6.

The survey shall be recorded digitally and submitted to the Engineer with a report identifying the condition of the casing, any corrosion, perforation, collapse, displacement or open joint, the condition and the degree of encrustation of the screen, the depth and nature of any obstruction or accumulated material, the depths of changes of casing diameter, and the water level at the time of the survey.

Where the survey, or abnormal wear on the pump as found, indicates that the well may be out of plumb or out of alignment, the Contractor shall carry out a verticality and alignment test to AWWA A100 over the length in which the pump is to be set, and shall report the result.

Where the condition of the casing is in doubt, the Engineer may instruct a caliper log, which shall be valued in accordance with the Contract.

The report shall be submitted within seven days of the survey. No equipment shall be installed in a well until the Engineer has accepted the survey and the report.

F.6. Cleaning and Development of the Well

Where the television survey, the sounded depth or the recorded yield shows that the well contains accumulated sand or silt, or that the screen is encrusted, the Contractor shall clean and develop the well before the new pump set is installed.

Cleaning and development shall be carried out by airlifting, by surging with a surge block, by jetting, or by a combination of these. Chemical treatment, including acidisation and the use of polyphosphate dispersants, shall not be carried out without the prior written approval of the Engineer, which shall be sought with the proposed chemical, dose, contact time, neutralisation and disposal arrangements, and shall be supported by the safety data sheets.

Development shall continue until all of the following are satisfied, measured at the intended test rate:

- the discharge is free of visible sediment;
- the sand content of the discharge does not exceed 5 mg per litre after 15 minutes of continuous pumping, measured by a centrifugal sand sampler or an equivalent method accepted by the Engineer;
- the turbidity of the discharge does not exceed 5 NTU;
- the specific capacity measured on two successive occasions not less than one hour apart differs by not more than 5 per cent.

The Contractor shall record the method, duration, rates, the volume of material removed and the depth sounded before and after development, and shall sound the well on completion to confirm that the accessible depth has been restored. Material and water removed shall be dealt with under Clause F.11.

F.7. Materials and Equipment in Contact with Well Water

Every material and item of equipment introduced into a well, and every material in contact with the water downstream of it, shall be certified as suitable for contact with potable water in accordance with Clause E.2.4.1.

Oil-lubricated equipment shall not be used in a well. Bearings shall be water-lubricated, or lubricated with a food-grade lubricant certified for contact with potable water. Thread compounds, jointing compounds and greases shall be of a potable-water grade approved by the Engineer.

Every item shall be cleaned of soil, grease and swarf, and shall be swabbed or sprayed with a chlorine solution of not less than 100 mg per litre free chlorine, immediately before it is lowered into the well. Equipment shall not be laid directly on the ground; clean racks or sheeting shall be provided.

F.8. Well Head Works

The Contractor shall reconstruct or make good the sanitary protection of the well head so that surface water and foreign matter cannot enter the well or the annulus. The works shall comprise, unless the Engineer directs otherwise:

- a reinforced concrete slab around the well, not less than 1.0 m in radius from the casing and not less than 150 mm thick, laid to fall away from the casing, and sealed to the casing;
- the casing projecting not less than 300 mm above the finished level of the slab, and above any level to which the compound is liable to flood;
- a sealed well cap or head plate, bolted and gasketed, with sealed entries for the rising column, the cables, the dip tube and the air line, and with a vent that is turned down, screened against vermin and insects, and of a size adequate to prevent pressure difference on starting;
- a water level access tube of not less than 25 mm internal diameter, fixed to the rising column and extending not less than 2 m below the lowest anticipated dynamic water level, together with an air line or a submersible pressure transducer for the continuous measurement of level;

- a discharge assembly comprising an isolating valve, a non-return valve, a pressure gauge with an isolating cock, an air valve, a sampling tap of a design that can be flamed, located upstream of any storage, and a flow meter complying with Clause G.33.21;
- the well head chamber or compound, drained so that it cannot flood, lockable, and fenced where the Bills of Quantities so provide.

Earthing, lightning and surge protection, the control panel, the variable frequency drive and the cabling shall comply with Parts G and H. Where the well is supplied from a photovoltaic array, Part I shall also apply.

F.9. Installation of the Pump Set

The pump set, rising column, cables and accessories shall comply with Clause G.37 and with Clause G.42. The setting depth shall be determined from the results of the pumping test carried out under Clause F.10 and from the requirements of the manufacturer, and shall be submitted for approval before installation.

Unless the Engineer approves otherwise, the pump shall be set not less than 3 m above the top of the uppermost screen and shall not be set within a screened length. Where the pump must be set within or below a screened length, a flow-inducing shroud shall be fitted. The submergence at the maximum anticipated drawdown shall be not less than the minimum required by the manufacturer, and the velocity of water past the motor shall be not less than the minimum required for cooling.

The rising column, the cable fixing and the centraliser shall comply with Clause G.37.8.2. The insulation resistance of the motor and of the cable shall be measured and recorded before lowering, at intervals during lowering, and after installation; the values and the instrument used shall be recorded and submitted.

On first starting, the direction of rotation shall be confirmed, and the voltage and the current in each phase shall be measured and recorded at no load and at the duty point, together with the frequency and, where a variable frequency drive is installed, the speed.

F.10. Pumping Tests

F.10.1 General

No well shall be returned to supply until it has been tested in accordance with this Clause in the presence of the Engineer and of a representative of the South Lebanon Water Establishment. The Contractor shall give not less than seven days' notice of a test, and shall have obtained the approval of the Engineer to the arrangements for the disposal of the test water under Clause F.11 before the notice is given.

Tests shall be carried out in accordance with ISO 14686 and with this Clause. A test interrupted for any reason shall be abandoned and repeated in full after the water level has recovered, unless the Engineer accepts otherwise in writing.

F.10.2 Measurement and Instruments

The following shall be measured and recorded throughout every test:

- discharge, by a calibrated flow meter, orifice plate or measuring weir, to an accuracy of ± 5 per cent or better, with the means of adjusting and holding the rate constant;
- water level in the well, by an electric contact gauge reading to 10 mm, or by a pressure transducer and logger of equivalent or better accuracy, measured through the dip tube from a fixed and recorded datum;

- elapsed time, by stopwatch;
- water level in any available adjacent well or observation point, and the level in the village storage;
- field conductivity, temperature, pH and turbidity of the discharge.

Every instrument shall have been calibrated within the twelve months preceding the test, and the calibration certificates shall be submitted to the Engineer before the test. The datum for water level measurement shall be surveyed and related to the top of the casing and to the site datum.

F.10.3 Pre-Test Observations

The static water level shall be recorded for not less than two hours before the test begins, at intervals not exceeding 15 minutes, and the test shall not begin until the level is stable within 10 mm per hour. The reading immediately before the pump is started shall be taken as the static water level for the test.

F.10.4 Step-Drawdown Test

A step-drawdown test shall be carried out comprising not fewer than four steps of 100 minutes each, run consecutively without recovery between steps, at rates spanning approximately 50 to 120 per cent of the intended duty of the well. The discharge in each step shall be held constant within ± 5 per cent and shall be recorded at the same intervals as the water level.

Water level shall be recorded from the start of each step at the following elapsed times, in minutes: 0.5, 1, 1.5, 2, 2.5, 3, 4, 5, 6, 8, 10, 12, 15, 20, 25, 30, 40, 50, 60, 80 and 100.

F.10.5 Constant-Rate Test

A constant-rate test shall follow, after the water level has recovered to within 100 mm of the static level or for not less than the duration of the step-drawdown test, whichever is the longer. The test shall be run for not less than 12 hours, or for 24 hours where the Engineer so instructs, at the rate determined from the step-drawdown test and approved by the Engineer, held constant within ± 5 per cent throughout.

Water level shall be recorded at the intervals given in Clause F.10.4 for the first 100 minutes, and thereafter at 120, 150, 180, 240, 300, 360, 480, 600 and 720 minutes, and at intervals not exceeding 120 minutes until the end of the test.

F.10.6 Recovery

Recovery shall be monitored from the instant at which the pump is switched off, at the intervals given in Clause F.10.4 and thereafter as in Clause F.10.5, and shall continue until the water level has recovered to within 10 per cent of the total drawdown, or for 12 hours, whichever occurs first. The time of switching off shall be recorded to the nearest second.

F.10.7 Interpretation and Report

The Contractor shall submit a report on each well within 14 days of the completion of the test, comprising the field records in full, the data in electronic form, and an interpretation giving:

- a) the drawdown and specific capacity at each step and at the constant rate;
- b) the aquifer loss and well loss coefficients derived from the step-drawdown test, and the well efficiency;
- c) the transmissivity, and the storage coefficient where an observation point was available, derived by a recognised method, with the plots on which the derivation is based;

- d) the analysis of the recovery data and a comparison with the drawdown analysis;
- e) the recommended sustainable abstraction rate and the corresponding dynamic water level, having regard to the abstraction authorisation and to the long-term behaviour indicated by the test;
- f) the recommended pump setting depth and duty;
- g) a comparison with the yield recorded for the well before the conflict, and an explanation of any material difference;
- h) a statement whether the pump set specified in the Bills of Quantities is correctly sized for the well as tested.

Where the test establishes that the well cannot sustain the duty on which the Works are based, the Contractor shall report the fact to the Project Manager without delay and shall not install or commission a pump set at that duty. The Project Manager shall determine, in consultation with the South Lebanon Water Establishment, the duty to be adopted, and any resulting change shall be instructed as a Variation and valued in accordance with the Contract.

F.11. Disposal of Development and Test Water

The volumes of water discharged during development and testing are substantial; a constant-rate test of 12 hours at 40 cubic metres per hour discharges approximately 480 cubic metres. The Contractor shall plan and obtain approval of the disposal of this water before the work begins, and shall allow in its rates and programme for doing so.

The discharge shall be conveyed to a point agreed in advance with the Engineer, the South Lebanon Water Establishment and the concerned municipality, and shall comply with the environmental and social management requirements of the Contract. The discharge shall not be made:

- to a watercourse, to the Litani River or to any seasonal watercourse, or to an irrigation channel;
- to a soakaway, excavation or depression within 50 m of the well, or at any point from which it may return to the well and invalidate the test;
- onto land liable to erosion, onto a road or a public area, or onto cultivated land or property without the written agreement of the occupier;
- in a manner that causes flooding, scour or nuisance.

Sediment-laden discharge shall be passed through a settlement tank or lagoon before release, and the retained solids shall be removed and disposed of under the waste provisions of the Contract. Water containing free chlorine shall be dechlorinated before release and the residual shall be measured and recorded. The volume discharged and the point of discharge shall be recorded for each operation.

F.12. Disinfection, Water Quality and Recommissioning

On completion of the installation, the well, the rising column, the well head pipework and the pipework to the point of connection shall be disinfected in accordance with AWWA C654 and Clause E.5. A chlorine solution giving not less than 50 mg per litre of free chlorine shall be introduced so as to reach the whole of the water column and the whole of the pipework; the solution shall be agitated by starting and stopping the pump, or by recirculation, so that it is distributed throughout; and the contact time shall be not less than 12 hours, at the end of which a free residual of not less than 25 mg per litre shall remain, failing which the operation shall be repeated.

The well and the pipework shall then be flushed until the free chlorine residual is at the level normally carried in the supply, and in any case below 1.0 mg per litre, and until the water is visually clear and the turbidity does not exceed 5 NTU. The water flushed to waste shall be dealt with under Clause F.11.

Two sets of samples shall then be taken from the sampling tap at the well head, not less than 24 hours apart, and shall be tested by an independent laboratory accredited for the tests concerned, or otherwise acceptable to the Engineer. Each set shall comprise, as a minimum:

- bacteriological: total coliform bacteria, *Escherichia coli*, and heterotrophic plate count;
- physico-chemical: turbidity, colour, odour, pH, electrical conductivity, total dissolved solids, total hardness, chloride, sulphate, nitrate, nitrite, ammonium, iron, manganese and free chlorine residual;
- any further determinand required by the South Lebanon Water Establishment for the well concerned.

Both sets shall comply with the Lebanese Standard NL 161 for potable water and, in respect of any parameter on which that Standard is silent, with the WHO Guidelines for Drinking-water Quality. Where a sample fails, the Contractor shall establish the cause, shall re-disinfect, re-flush and re-sample at its own cost, and shall repeat until two successive compliant sets are obtained.

No well shall be returned to supply until the Engineer and the South Lebanon Water Establishment have accepted the results in writing.

F.13. Records and Handover

The Contractor shall compile a well file for each well, in two hard copies and one electronic copy, and shall deliver it to the South Lebanon Water Establishment through the Engineer before the issue of the Certificate of Completion. The file shall contain:

- the Well Data Sheet required by Clause F.2, as finally completed;
- the television survey recordings and reports required by Clause F.5, and any verticality or caliper record;
- the record of cleaning and development required by Clause F.6;
- the full pumping test records and the report required by Clause F.10.7;
- the installation record, giving the setting depth, the serial numbers of the pump, motor, drive and meter, the insulation resistance readings and the electrical readings taken on commissioning;
- the disinfection record and the laboratory certificates required by Clause F.12;
- the as-built drawing of the well head and compound, and the operation and maintenance manuals and spares lists for the equipment installed.

The Contractor shall instruct the operating staff of the South Lebanon Water Establishment in the operation and maintenance of the installed equipment, including the measurement of water level through the dip tube, the reading and recording of the flow meter and the energy meter, and the action to be taken on an alarm; and shall record the instruction given and the staff attending.

Technical Specifications

Mechanical Works

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G.1 General

G.1.1 Summary

- A. This section generally specifies administrative and procedure requirements regarding Mechanical Work. Additional requirements are specified in various sections and also as may be required during the execution work due to project conditions.
- B. The requirements of this Section do not supersede or take precedence over any provision of the General Conditions and Supplementary General Conditions, and should any discrepancy become apparent between these requirements and the General Conditions and Supplementary General Conditions, the Contractor shall notify the Engineer and the Owner's Representative in writing, and the Engineer and the Owner's Representative shall interpret and decide such matters in accordance with the applicable provisions of the General Conditions and Supplementary General Conditions.
- C. This Specification sets out the general standards of the Facilities to be supplied by the Contractor and mention of any specific Plant and Equipment does not necessarily imply that such is included in the Facilities. All component parts of the Facilities shall, unless specified otherwise, comply with the provisions of this Specification. The names of the manufacturers of the Plant and Equipment proposed for incorporation in the Facilities together with performance, capacities, certified test reports and other significant information shall be provided, when requested, for consideration by the Engineer. The Engineer shall have power to reject any Plant and Equipment which in his opinion is unsatisfactory or not in accordance with this Specification and such Plant and Equipment shall be replaced by the Contractor at no extra cost to the Buyer.

G.1.2 Adherence to Standards

This Specification sets out the general standards of the Facilities to be supplied by the Contractor and mention of any specific Plant and Equipment does not necessarily imply that such is included in the Facilities.

All component parts of the Facilities shall, unless specified otherwise, comply with the provisions of this Specification or equivalent.

The names of the manufacturers of the Plant and Equipment proposed for incorporation in the Facilities together with performance, capacities, certified test reports and other significant information shall be provided, when requested, for consideration by the Engineer. The Engineer shall have power to reject any Plant and Equipment which in his opinion is unsatisfactory or not in accordance with this Specification and such Plant and Equipment shall be replaced by the Contractor at no extra cost to the Buyer.

G.1.3 Standards, Regulations and Engineer's Approval

The design, workmanship, materials, strength and dimensions of all parts shall be the satisfaction of the Engineer and shall comply with one or more of the standards, regulations and codes issued by the following:

German Industrial Standards (DIN) and Standards of the Association of German Electrical Consultants (VDE). Internationally recognised and technically equal standards subject to the approval of the Engineer, (such as EN, ISO, IEC, ASME, ASTM, API, NEMA, JIS). British Standards Institution (BS) and Regulations of the Institution of Electrical Consultants, UK. French Standards of the Association Francaise de Normalisation (AFNOR) and the Union Technique de l'Electricite (UTE). Equivalent Local Standards.

All ductile iron pipes, pieces, joints, connections, parts and accessories shall comply with the following Standards, Norms and Specifications:

Pipes NF A 48-801, NF A 48-806, NF A 48-841, ISO 2531, EN 545-2002, EN598.

Connections and joints NFA 48-863, NF A 48-842, NFA 48-830, NF A 48-860, NFA 48-870, BS EN 545-1998, ISO 2531.

Joint's fittings : NF T 47-305, ISO 4633

External Protection (Zinc coating : NF A 48-852, ISO 8179

External Protection (Bituminous coating) : EN 545-2002, EN 598

Internal Protection (Cement mortar) : NF A 48-901, NF A 48-806, ISO 4179, EN 545, EN 598.

Excellency of Productions and Installations : ISO 9001

Testing : ISO 2531

Special Protection (Polyethylene) : ISO 8180

Alternative standards may be adopted, provided that:

they are appropriate and do not conflict with any requirement of the Specification;

that an English translation of each such standard is supplied to the Engineer by the Contractor; and

that a list of such standards is submitted with the tender.

Where no standards are stated in the Contract, all materials, components, equipment, workmanship and tests for which DIN or their acceptable equivalents have been issued, shall be in accordance with such standards.

The electrical installations shall comply with and be tested in accordance with national or internationally recognized regulations or codes of practice subject to any specific requirements of the local electricity supply authority.

Material and equipment supplied and work performed shall comply with these standards and regulations as a minimum. Where manufacturers offer equipment to other standards, the standards shall be equal or superior to those specified and full details of the difference shall be supplied to the Engineer if requested.

Where the design or choice of materials or plant is affected by Statutory Safety Acts, then the materials and plant supplied shall comply with all relevant sections of those acts even though no particular reference may be made in the Specification.

G.1.4 Mixture of Standards

The Contractor should note that the Engineer will not approve of any complete system incorporating component parts and design standards to different National Standards unless the entire system has been designed to function as a whole within the standards and design codes laid down by only one of the foregoing approved authorities.

G.2 Design And Design Life

The Contractor shall design the Works in accordance with the specification and to the satisfaction of the Engineer. The design of plant shall be in accordance with good modern practice and shall be such as will facilitate operation,

inspection, cleaning, lubrication and repair to ensure long life and satisfactory operation under all service conditions. The Contractor's design calculations shall be submitted to the Engineer as required.

Plant shall be designed for a long reliable operating life and shall be suitable for 24 hours per day continuous operation for prolonged periods in the climatic conditions applying and with a minimum of maintenance. The Contractor may be called upon to demonstrate this for any component, either by the service record or evidence of similar equipment already installed elsewhere or by records of relevant type tests.

Wherever possible, plant shall be designed and arranged so that the degree of skill required to maintain and service the Works shall be minimal. Except for consumable items, which normally require more frequent replacement, no part subject to wear shall have a design life from new to replacement or repair of less than five years of continuous normal operation, and, where major dismantling is required to replace a part, the life of such parts shall not be less than ten years.

The Works shall be designed for the prevention of corrosion, entry of insects and vermin, entry of dirt and dust, and to minimize risk and damage in the event of a fire. Plant shall operate without undue vibration and parts shall be designed to withstand the maximum stresses under the most severe conditions of normal service after loss due to any corrosion allowance, or the specified test condition including any corrosion allowance.

Plant shall be designed so that when operating at the normal condition, the intensity of emitted noise in the working environment shall not constitute a health hazard to operators and other personnel or cause a nuisance outside the boundary of the Works. The anticipated noise characteristics of all items of plant and systems which have high noise potential shall be submitted to the Engineer early in the design stage of the Contract.

The Contractor shall ensure that all pollutants are discharged from the Works in a controlled and safe manner.

The style and finish of the plant installation shall be consistent throughout the Works, water works finish applying throughout.

Design Safety Features:

Plant, as designed and installed, shall have no feature that could be a hazard to operators, maintenance staff, visitors or other persons having access thereto. Guard electrical safety devices, thermal insulation, noise suppression devices, written notices, safety covers, lifebelt and the like shall be provided where needed.

Adequate safeguards shall be provided to prevent personnel accidentally coming into contact with dangerous machinery mechanisms, hot surfaces, electrically live parts and any other hazardous components or contents.

Emergency stop devices shall be provided and positioned adjacent to all driven plant which: involves a risk of injury to personnel during norm and maintenance operations; handles high pressure fluid or dangerous chemicals; is located at a distance of more than five metres from its controller; has no direct, unimpeded access between the controller and the item of controlled plant, irrespective of distance.

Secure and substantial guards shall be supplied throughout the installation to cover drive mechanisms. All rotating and reciprocating parts, drive belts, etc. shall be shrouded to removable for gaining access to the plant without the need to first remove or displace any major item of plant; and they should also allow for adequate ventilation.

Guards shall not have to be removed during normal operation running maintenance and routine inspections, and shall be designed to prevent access of fingers to the moving parts.

Rubber mats shall be provided by the Contractor in front of all motor control centres, distribution boards, and instrument and battery supply power cabinets supplied by them under the contract.

G.2.1 Plant Design

Plant shall be new, of sound workmanship and robust design, and of a grade and quality suitable for the climatic and working conditions at the Site.

Due attention shall be given to expansion due to temperature changes, the stability of paint finish for high temperatures, the rating of engines, electrical machinery, thermal overload devices, cooling systems, and the choice of lubricants for the possible prolonged high operating temperatures. Suitable precautions, such as lagging or trace heating, shall be taken where necessary for protection against damage by frost.

Plant shall be designed to provide protection against damage by the entry of vermin and dust, and to minimize fire risk and consequent fire damage. It shall also be protected against damage due to dampness and condensation by sealing or temperature compensation.

All manually controlled Plant located outside a building shall be provided with facilities for making it tamperproof. This is in addition to any requirements for securing Plant under operational conditions.

All component parts of Plant shall be manufactured to strict limits of accuracy and shall be interchangeable with the component parts of similar Plant.

Plant shall be designed for continuous operation for prolonged periods with a minimum of maintenance and shall have a high resistance to change in these properties due to passage of time, exposure to light or any other cause which may affect the performance or life of the Works. Tenderers should be called upon to demonstrate this for any equipment under consideration either by service records of similar equipment, or by the records of extensive type tests.

Materials shall be selected taking into consideration their location and duty. In the case of Plant conveying water, particular attention shall be given to the risk of electrolytic reaction between differing materials of construction and to the effects of corrosion and, where there are impurities in the water, erosion.

Where wear is likely to occur during normal operation, the Plant shall be designed to enable a potentially affected area of a component part to be replaced without replacing the whole component. No part subject to wear shall have a life from new to replacement or repair of less than one year of continual operation. Where major dismantling to replace a part cannot be avoided, the life of such parts shall not be less than 5 years.

The Contractor shall supply all labor, materials, equipment, tools, appurtenances, storage, services and temporary work, necessary to completely install, in accordance with these specifications.

Work, materials, equipment or services not specifically mentioned in other clauses of these specifications or elsewhere, but found necessary for the completion and perfect functioning of the installations must be included in the Contractor's price.

The work shall include also operation of the installations after completion and acceptance including maintenance and guarantee of the works as described hereinafter.

The work shall be designed and carried out in accordance with the contract specifications, as well as the standards of the country of origin. It shall be clearly understood that these specifications are complimentary documents, intended for the selection of equipment having the general and specific characteristics as detailed in the documents.

G.3 Metals

Unless stated otherwise cast iron shall be gray iron to ISO 185 Grade 220. Mild steel shall be to ISO 1052.

Stainless steel shall have a corrosion resistance, in the relevant environment, not less than required for steel in accordance with ISO 683 - 13. The minimum grades of stainless steel used shall be:

- a) Submerged conditions; Austenitic grade 316S12 b) Exposed to the ambient atmosphere; Martensitic grade 416S21

Stainless steels used for welding shall be a grade not subject to inter-granular corrosion. Prevention of seizure, by fretting where two corrosion resistant metals are in contact, shall be by selection of suitable relative hardness and surface finish and/or lubrication.

Where bronze is specified, or used, it shall be zinc free.

Dissimilar metals in contact shall be selected so that the electrolytic potential difference does not exceed 0.6 volt unless the surface area of the lower potential metal is negligible. Alternatively an approved insulation material shall be used.

When the Engineer requires the submission of material samples for assessment they shall be submitted by and at the expense of the Contractor not less than thirty calendar days prior to the time that the material is required for incorporation into any Plant and Equipment. Samples shall be subject to written approval by the Engineer and shall not be used without such approval.

G.4 Welding

All welding shall be carried out either manually by the shielded metallic arc process or automatically by the shielded arc or submerged arc method.

The Contractor shall submit a welding procedure for the approval of the Engineer in the same manner. After the welding procedure has been approved, the Contractor shall record it on a special drawing which shall thereupon become one of the drawings of the Contract. Weld sizes and types shall be shown on all Contractor's drawings where welding is required.

Plates to be joined by welding shall be accurately cut to size and rolled by pressure to the proper curvature which shall be continuous from the edge. Flattening in the curvature along the edges with correction by blows will not be allowed. The dimensions and shape of the edges to be joined shall be such as to allow thorough fusion and complete penetration and the edges of plates shall be properly formed to accommodate the various welding conditions. The surfaces of the plates for a distance of 25mm from the edge to be welded shall be thoroughly cleaned of all rust, grease and scale, to bright metal.

The technique of welding employed, the appearance and quality of the welds made and the methods used in correcting defective work, shall conform to the ISO 2553 and 3041.

All welders and welding operators assigned to the Works shall have passed a qualification test, within the preceding six months, for welders and welding operators, complying with ISO standards. The Contractor shall furnish the Engineer with three (3) certified copies of report of the results of physical tests of specimens welded in the qualification tests. If, in the opinion of the Engineer, the work of any welder at any time appears questionable he shall be required to pass the appropriate re-qualification test. All costs of qualification tests shall be borne by the Contractor.

Welding electrodes and filler wires shall comply with the appropriate ISO and/or EN standards applicable for the metal/s being welded

G.5 Castings

The structure of the castings shall be homogeneous and free from non-metallic inclusions and other defects. All surfaces of castings which are not machined shall be fettled to remove all foundry irregularities. All castings shall be to the appropriate grade, dense, sound and true to pattern, of workmanlike finish and of uniform quality and condition, free from blowholes, porosity, hard spots, shrinkage defects, cracks or other injurious defects, and shall be satisfactorily cleaned for their intended purpose. Minor defects not exceeding 10 mm in depth or 10% of total metal thickness whichever is less or which will not ultimately affect the strength and serviceability of the casting may be repaired by welding. If the removal of metal for repair should reduce the stress-resisting cross-section of the casting by more than 25%, or to such an extent that the computed stress in the remaining metal exceeds the allowable stress by more than 25%, then that casting shall be rejected. Castings shall not be repaired, plugged, or welded without permission of the Engineer. Such permission will be given only when the defects are small and do not adversely affect the strength, use, or machinability of the castings. Excessive segregation of impurities or alloys at critical points in a casting will be cause for its rejection. Castings repaired by welding for major defects shall be stress-relieved after such welding or as otherwise instructed in writing by the Engineer.

Surfaces which do not undergo machining and are exposed in the final installation shall be dressed to provide a satisfactory appearance so that they will not require surface smoothing at the Site prior to painting. Non-destructive tests may be required for any casting containing defects whose effect cannot otherwise be established, or to determine that repair welds have been properly made. Unless otherwise specified castings shall be produced to the following Standards: Iron castings shall be in accordance with ISO 2531. Steel castings shall be fully annealed and shall be in accordance with: ISO 4990, BS 3100 Steel alloy and Flake graphite cast iron BS 1452 Grade 220 Copper & copper alloy BS 1400 Group A grade LG2 Group B grade CT1, AB2 Group C grade G1

G.6 Forgings

Forging shall be in accordance with ISO standard. The ingots from which the forging are made shall be cast in metal moulds, the workmanship shall be first-class in every respect and the forging shall be free from all defects affecting their strength and durability, including seams, pipes, flaws, cracks, scales, fins, porosity, hard spots, excessive non-metallic inclusions and segregation. All major stress-bearing forgings shall be submitted to the Engineer for approval before work is commenced. They shall be subject to internal examination and non-destructive tests for the detection of flaws, and shall be heat-treated for the relief of residual stresses. The name of the maker and particulars of the heat treatment proposed for each such forging shall be submitted to the Engineer. The Engineer may inspect such forgings at the place of manufacture with a representative of the Contractor.

G.7 Mild Steel Plate And Bars

Structural steel and flat bars shall be in accordance with ISO 657. Steel bolts, nuts and washers shall be in accordance with ISO 262/887. Corrosion-resistant steel and bars shall be in accordance with ISO 3651.

G.8 Machine Work - General

All tolerances, allowances and gauges for metal fits between plain cylindrical parts shall conform to ISO 286 for the class of fit as shown or otherwise required. Bearing surfaces shall be true and exact to secure full contact. Journal and sliding faces shall be polished and all surfaces shall be finished with sufficient smoothness and accuracy to ensure

proper operation when assembled. Parts entering any machine shall be carefully and accurately machined. All drilled holes for bolts shall be accurately machined. All drilled holes for bolts shall be accurately located and drilled from templates.

G.9 Machine Work - Finished Surfaces

Surface finish shall be indicated in the Contract and shall be in accordance with ISO Standards or equivalent. Compliance with specified surface finish will be determined by sense or feel and by visual inspection of the Work compared to standard roughness specimens, in accordance with the provisions of the above stated standards.

G.10 Machine Work - Unfinished Surfaces

So far as is practicable, all work shall be arranged to obtain proper matching with adjoining unfinished surfaces. When there is a large discrepancy between adjoining unfinished surfaces, they shall be chipped and ground smooth, or machined, to secure proper alignment. Unfinished surfaces shall be true to the lines and dimensions to be shown on the Contractor's approved shop drawings and shall be chipped or ground free of all projections and rough spots. Depressions or holes not affecting the strength or usefulness of the parts may be filled in an approved manner.

G.11 Machine Work - Keys And Keyways

Keys and keyways shall conform to the requirements of ISO Standard or other approved equivalent standards, unless otherwise specified or required.

G.12 Machine Work - Pins And Pin Holes

Pin holes shall be bored to gauge, smooth and straight, and at right angles to the axis of the member. The boring shall be done after the member is securely fastened in position. Pins shall be of hardened and ground steel and positively held in position. Wheels or rollers for use in gates shall be mounted on removable pins and have self lubricating bushings and brass washers.

G.13 Lubrication

Before assembly, all bearing and journal surfaces grease and oil grooves shall be carefully cleaned and lubricated with an approved oil or grease. After assembly, each lubricating system shall be filled with an approved lubricant. Self-lubricating bearings shall be cleaned with clean rags, and greased with an approved lubricant before assembly; solvents shall not be used on the self-lubricating, bearings. The specification of all approved lubricants shall be mentioned in the operating and maintenance instructions.

G.14 Balancing

All complete rotating assemblies shall be dynamically balanced. Balance quality shall not be less than G6.3 in accordance with ISO 1940/1

G.15 Non-Metallic Materials

Fabrics, cork, paper and similar materials which are not subsequently to be protected by impregnation shall be treated with a fungicide. Sleeving and fabrics treated with linseed oil varnish will not be permitted. The use of organic materials shall be avoided as far as possible but where these have to be used they shall be treated to make them fire resistant and non-flame propagating.

The use of wood shall be avoided as far as possible. If used, woodwork shall be thoroughly seasoned teak or similar hardwood which is resistant to fungal decay and other blemishes. All woodwork shall be treated to protect it against damage by fire, moisture, fungus, vermin, insect, bacteria or chemical attack, unless it is naturally resistant to all these. All joints in woodwork shall be dovetailed or tongued and pinned. Metal fittings on wood shall be of non-ferrous material. Adhesives shall be impervious to moisture and fungus growth. Synthetic resin cement only shall be used for joining wood. Casein cement shall not be used.

G.16 Bolts, Screws, Studs, Washers And Nuts

Bolts, screws, studs and nuts shall comply with ISO 225, ISO 272, ISO 885, ISO 888, ISO 898, ISO 8992 and ISO 4759/1. Washers complying with ISO 887 and ISO 4759/3 shall be used under all nuts and hexagon bolts and screws. Bolts, screws, nuts and washers exposed to the weather or in damp atmospheres inside buildings shall be zinc coated and painted or stainless steel. All holding-down and anchor bolts, nuts, washers and anchor plates for use internally in areas not subject to contact with water or sewage shall be steel galvanized to BS EN ISO 3834-1:2005 and all exposed surfaces shall be painted after assembly and tightening. ISO 1460 and ISO 1461, are accepted also. The threads of nuts shall be cut oversize. Stainless steel items shall be manufactured from Grade 316S31.

Bolting for pipes and fittings shall comply with ISO 7005. Spheroid graphite iron bolts for use with ductile iron pipes and fittings shall be manufactured from iron complying with ISO 1083. 3 mm thick washers shall be fitted beneath bolt and nut. Bolts shall project beyond the nut by between two and three threads.. All bolts, nuts, washers and anchor plates, except high tensile, for all ferrous parts shall be steel galvanized according to national applicable standards and norms in force, primed and painted after assembly and tightening.

All bolts, nuts, washers and anchor plates, for fastening galvanized components or aluminium alloy components shall be of stainless steel Grade 1.4401, EN 10088 and shall remain unpainted. PTFE washers shall be fitted beneath stainless steel washers for both bolthead and nut.

Stainless steel (grade 1.4432 or 1.4435, SR EN 10088:2009) shall be used for those subjected to continuous or occasional immersion and those in corrosive atmospheres, and for those which require removal or adjustment during maintenance or repair of the plant.

All bolts, nuts, studs and washers used in the construction of pumps shall be stainless steel Grade 1.4401, BS EN 10088:2009.

All holding-down bolts, nuts, washers and anchor plates for use externally or in internal areas which are subject to contact with water or in “wet” areas but above the top water level shall be of high tensile stainless steel Grade 1.4401, BS EN 10088:2009.

Drilled anchor fixings for use on concrete structures shall be of a chemical type approved by the Engineer.

All exposed boltheads and nuts shall be hexagonal and the length of all bolts shall be such, that when fitted with a nut and tightened down, the threaded portion shall fill the nut and not protrude from the face thereof by more than a half diameter of the bolt.

No on-site processing or cutting of threading rods is allowed.

Precision bolts, nuts and washers shall be used for the assembly of machines and electrical Plant.

Bolts, nuts and washers (other than those of stainless steel), pipe hangers and small fixings generally, shall be hot dipped galvanised to SR EN ISO 1461:2009. Screw threads shall be undercut prior to galvanising to prevent stripping. Insulating washers and sleeves shall be fitted where necessary to safeguard against galvanic corrosion.

For general purpose cone head rivets are preferred. Rivets on the support surface shall be of buried head type. Whenever possible, riveting shall be made with hydraulic or pneumatic tools, and they shall completely fill the holes after assembly. If they are loose or if the ends are poorly made, cracked, offset from the tail or do not really support the plate or bar, rivets shall be removed and replaced. All riveted surfaces shall be in direct contact across the entire assembled surface.

All jointing material shall be provided.

G.16.1 Fixing Bolts

Fixing bolts, nuts and washers for concrete, brick or masonry shall be of stainless steel. The bolts may be rag or indented bolts, expansion bolts, or resin bonded bolts. The Contractor shall submit details of the type he proposes to use, including manufacturer's specification literature, for the Engineer's approval. When the bolts etc., are used for fixing aluminium items they shall be insulated from the aluminium by a non-metallic sleeve and under-washer.

The building-in material for use with rag or indented bolts shall be a proprietary epoxy non-shrink grout or a proprietary non-shrink mortar or caulking compound. Bolts shall not be brought into service until they are effectively anchored and the building in material has achieved adequate strength.

G.17 Lubrication

G.17.1 General

Provision shall be made for suitable lubrication to ensure smooth operation, heat removal and freedom from undue wear. Plant selected shall require minimum lubrication attendance and down time for lubricant change.

All grease nipples, oil cups and dip sticks shall be readily accessible, being piped to a point as near as practicable to the lubrication point.

The Contractor shall catalogue all the lubricating points, the suitable lubricant or oil and the recommended service interval in the form of a chart. The Contractor must include all the necessary oils and lubricants for the initial filling and for the first year of operation so that the testing and commissioning operation might be carried out without undue delays.

The Contractor has the responsibility to make sure that the lubricating devices have been filled with oils and they have been applied on all the nipples, before starting up the machinery.

The Contractor shall provide the Supervision Consultant with a detailed list of lubricants, for approval purposes, and, at the time of the commissioning, the lubricants shall be checked in relation to the approved list. Likewise, the Contractor shall make sure that the lubricants used or their equivalents can be obtained on the local market.

G.17.2 Oil Lubrication

Gear boxes and oil baths shall be provided with adequately sized filling and draining plugs and suitable means of oil level indication. Roller chain drives shall have oil bath reservoir lubrication.

Drain points shall be located or piped to a position such that an adequately sized container can be placed beneath them. Where a large quantity of oil is involved or drainage to a container difficult, a drain valve and plug shall be provided at the point of discharge.

Bearings equipped with forced fed oil lubrication shall be automatically charged prior to machinery starting up and pressure monitored during operation with automatic shutdown of machinery and alarm on low oil pressure.

All points where oil leakage may occur shall be suitably trapped to prevent oil contamination of water. Oil filling and drain points shall be arranged so as to avoid the risk of contamination of water by accidental spillage.

Access, without the use of portable ladders, to lubrication systems shall be such as to permit maintenance, draining and re-filling, without contamination of the charged lubricant.

The design of breathers shall take into account the humidity and atmospheric contamination at the vent point and measures be incorporated to prevent contamination of the lubricant.

G.17.3 Grease Lubrication

Grease application shall be by steel lubrication nipples. Anti friction bearings requiring infrequent charging shall be fitted with hydraulic type nipples.

Plain bearings requiring frequent charging shall be fitted with button head pattern nipples.

A separate nipple shall be provided to serve each lubrication point. Where a number of nipples supply remote lubricating points they shall be grouped together on a conveniently placed battery plate.

G.18 Gaskets And Joint Rings

Joint rings suitable for hot or cold water or specified hydrocarbon fluids or for drainage applications shall be of chloroprene rubber or other approved synthetic material suitable for temperatures up to 80 °C, or greater to suit the application. Until immediately required for incorporation in a joint, each rubber ring or gasket shall be stored in the dark free from the deleterious effects of heat or cold, and kept flat so as to prevent any part of the rubber being in tension. Graphite grease or similar shall be applied to the threads of bolts before joints are made.

G.19 Noise

No item of Plant intended for installation in a building shall produce a sound pressure level exceeding 85 dB (A) and preferably 56 dB(A) when measured at a distance of 1 m from the reference surface of that item in a horizontal direction and under environmental conditions appropriate to the test requirements of I.S.O. 3746 "Acoustic Determination of Sound Power Levels of Noise Services - Survey Methods".

Plant such as compressors, diesel engines, blowers etc. where reduction of noise emission to below 85 dB at 1 m is impractical will be installed in a separate room constructed in or containing sound absorbing material.

For soundproofing materials, the design of the works must include rubber holders or other suitable devices to make sure that the machines run without making any noise or excessive vibration after their installation in their final positions.

The Contractor shall include all the specific measures of sound absorption and shall notify the Supervision Consultant if the former believes that the noise in the plant will exceeds the specified level, after the incorporation of noise absorption measures. The noise testing measurements shall be carried out upon completing the installation of the machine on site, in order to verify that this provision is observed. The machines that do not comply with the limits in terms of noise levels when tested run the risk of being rejected, except when satisfactorily modified at the Contractor's expense, by the scheduled date of commissioning.

The measurement of the noise level, when necessary, must be carried out with a sound meter which is in accordance with SR-EN61672 and is equipped with a weighting network. The noise level is measured in dB(A).

G.20 Vibration

All items of rotating machinery shall be dynamically balanced. The vibration limits for rotating electrical machines must be in accordance with EN 60034.

The motor vibration shall not exceed the limits specified in the ISO 10816 -1 standard.

This limit on vibration shall extend to the communicating pipe work and mounting arrangements and include adjacent machinery either in operation or not.

All the bearing parts must be appropriately balanced, both statically and dynamically, so that, in operation, at fully normal operational speeds and under any loads, there is no excessive vibration anywhere in the machine transferred next to the structure. The criterion adopted for vibrations is the actual speed of vibration in millimetres per second.

The instruments for measuring vibrations must be in accordance with ISO 2954.

G.21 Access Steelwork

Gaps between items of Plant and the surrounding structure shall be covered, and access ladders, platforms and handrails must be attached to items of Plant to facilitate operation, inspection or maintenance.

Adequate access shall be provided to all hand wheels, sight glasses, gauges, lubrication points and any other items to which access is necessary for routine maintenance.

Handrails shall consist of double ball forged steel standards with tubular rails. Chequer plating shall be of 'Durbar' or other non-slip pattern, not less than 4.5 mm thick (exclusive of pattern).

Diamond type pattern chequer plate shall not be used. Open type or solid type chequer plate flooring shall be used as appropriate for the location, taking into account ease of cleaning, precautions against slipping and areas below walkways.

All components for access steelwork shall be hot dip galvanized after manufacture.

G.22 Handrailing

Hand railing shall be double rail 1,100 mm high and 900 mm high on stairs measured vertically from the nose of the tread.

In case of no special requirements of the Engineer, standard hand railing shall be 38 mm diameter solid forged steel with 60 mm diameter solid forged steel balls at handrail locating points. Standards shall have a minimum base width of 65 mm and be set at maximum 1 800 mm centres.

Handrails shall be 33.7 mm OD x 3.2 mm thick tubular steel Joints shall be arranged to coincide with the spacing of standards where possible, otherwise they shall have butt joints with a tubular steel ferrule, plug welded or fixed with a 5 mm diameter countersunk head pin.

Removable sections of handrail shall have half-lap joints secured with a countersunk head pin.

Chains across openings shall be 10 mm x 3 links per 100 mm galvanized mild steel. The hooks and retaining eyes shall be securely fixed to the balls of the standards.

All components for hand railing shall be hot dip galvanized after manufacture.

G.23 Painting And Protection

G.23.1 General

Protective coatings shall comply with BS 5493 "Code of practice for the protective coating of iron and steel against corrosion" except as otherwise specified in this section. For coatings designed to BS 5493 exterior conditions shall be assumed to be "polluted inland" conditions and the interiors of buildings shall be assumed to be "frequently damp or wet" except for control rooms. The thickness of coatings stated in this section of the specification is the minimum allowable thickness as defined in Clause 19 of BS 5493. Where the paints that are available do not provide dry film thickness as specified additional coatings shall be applied.

Protective coatings for surfaces of tanks and other plant in contact with chemicals or otherwise in conditions not foreseen in this section of the specification or in BS 5493 shall be suitable for those conditions and shall be the subject of design submissions supported by evidence proving satisfactory experience of the proposals elsewhere.

Where dissimilar metals are in contact, insulation shall be provided to prevent electrochemical corrosion.

The protective coating system shall have a minimum 10 year life to first maintenance. A five year minimum performance warranty shall be given in respect of the paint as applied.

All coatings applied to any part of the plant in contact with water to be used for drinking, washing or cooking shall be non-toxic, non-carcinogenic, shall not impart taste, odour, colour or turbidity to the water or foster microbial growth and they shall be approved by an international recognized authority for use on potable water.

To avoid the possibility of the presence of carcinogenic polyaromatic hydrocarbons all bituminous paints and coatings must be manufactured from petroleum or asphaltic bitumen and not from coal tar bitumen.

Lead based paints shall not be used.

All machined, polished or bright surfaces, both external and internal, shall be afforded suitable and adequate protection against corrosion, damage and deterioration.

No manufacturer's name plate identification, vented filler plugs in gearboxes or grease nipples shall be painted over.

Steel subject to hydrogen embrittlement through galvanizing shall not be used.

All iron and steelwork to be painted shall be blast cleaned to achieve a surface profile with minimum amplitude of 0.025mm and a maximum of 0.100mm.

Following blast cleaning, steel surfaces shall be pure zinc metal sprayed where specified. Aluminium structures and fittings shall not necessarily be painted.

All steel fabricated pipe work and other plant, where specified, shall have a lining and coating, not less than 250 microns thick, of 100% solids, thermosetting fusion bonded dry power epoxy coating.

GRP covers and guards shall be pigmented to give the finished colour without painting.

G.24 Coating Systems

Tables A and B identify the coating systems to be used and minimum coating thickness.

TABLE A: REQUIRED COATING SYSTEMS AND MINIMUM COATING THICKNESSES FOR PLANT AND EQUIPMENT

	APPLIED PRIOR TO DELIVERY AND ERECTION					APPLIED FOLLOWING
	SUBSTRATE	PRETREATMENT	FIRST COAT	SECOND COAT	THIRD COAT	INSTALLATION FINISHING COAT
ABOVE WATER LEVEL Machinery & Steelwork not in contact with Sewage, sludge or Water to be used for drinking, washing or cooking	Steel (galvanized)	Etch Prime or T Wash	Zinc Phosphate/CR Alkyd Primer Undercoat (0.050mm)	High Build Chlorinated rubber Paint (0.075mm)		High Build chlorinated rubber paint (0.075mm)
	Steel Zinc Sprayed (0.070mm)	Etch Prime				
	Steel, Cast iron, Ductile iron	Blast clean BS 4232 2nd quality	Zinc Phosphate/CR Alkyd Blast Primer (0.050mm)	Zinc Phosphate Alkyd Primer (0.050mm)	High Build Chlorinated Rubber (0.075mm)	
BELOW WATER LEVEL Machinery and Steelwork in Contact with Water to be used for drinking, washing or cooking	Steel (Galvanized)	Etch Prime or T Wash	Epoxy Primer High Build (0.125mm)	Epoxy High Build (0.50mm)	Epoxy High Build (0.075mm)	
	Steel, Cast iron, Ductile iron Zinc Sprayed (0.70mm)	Etch Prime				
Pipe work	Steel	As specified				
Switchboard Shells, Frames and Back plates	Steel	As specified				

TABLE B: REQUIRED HEAT RESISTANT COATING SYSTEMS FOR STEELWORK

WORKING TEMPERATURE	AL: SURFACE TREATMENT	FIRST COAT	SECOND COAT	THIRD COAT
50°C to 175°C	Blast clean BS	Polyvinyl Butyral (0.025mm) Zinc	Aluminium heat	Aluminium heat

	4232 2nd quality	Chromate Primer (0.023m-0.015mm)	resistant @ 200°C (0.025mm)	resistant @ 200°C (0.025mm)
175°C to 500°C	Blast clean BS 4232 2nd quality	Aluminium pigmented silicone heat resistant (0.025mm)	Aluminium pigmented silicone heat resistant (0.025mm)	
NB A minimum temperature of 350°C within a short time after application is required.				

G.25 Seals

G.25.1 General

Seals compatible with the Plant and best suited for the worst conditions likely to be met when the Plant is in operation shall be selected.

All seal materials shall be compatible with and/or resistant to the fluid or gas being handled. For potable water, seal materials shall be specifically approved.

G.25.2 Soft Packed Glands

Shafts shall be provided with renewable gland sleeves. Glands subject to abrasive liquors or negative pressures shall embody suitably positioned lantern rings and a clean water continuous flushing system, operative whenever the Plant is in motion.

Gland adjustment nuts shall be readily accessible for routine maintenance.

Gland drain pipe work shall be installed, incorporating rodding facilities and adequate inclines, of 25mm minimum diameter on water reclamation plant and 12.5mm on water supply plant, discharging to the nearest sump or drainage channel.

The glands must be fitted with removable gaskets. The glands for abrasive liquids or negative pressures must have suitable built-in lubricating rings and a continuous clean water washing system in operation whenever the machine is in motion.

The nuts for regulating the glands must be easily accessible for routine maintenance.

G.25.3 Mechanical Seals

Mechanical seals which are subject to abrasive liquor or gas, negative pressures or corrosive elements, shall be provided with a clean water continuous gland flushing system, operative when the item of plant is in motion or the corrosive element present. A back-to-back sealing arrangement with a flushing/cooling system shall be accepted as satisfying the requirements of this clause.

G.26 Bearings

G.26.1 General Conditions

Ball and roller bearings within gearboxes shall be rated for a minimum lifespan of 50,000 hours (preferable lifespan of 100,000 hours). Protected bearings shall have 50,000 hours basic rating life. Gearboxes shall have a guaranteed operating life of 30,000 hours and an operating life of 30 years.

The bearings must be designed for a load 25% higher than the maximum calculated load and must be suitable for reverse rotation at 150% rated speed compared to the maximum reverse speed of the pump in mounting conditions when the flow runs in the reverse direction if it is greater.

The bearing shells and their support must be made of a type of material that can withstand the flow with adequate strength and stiffness to cope with the loads set by the operation of the equipment in accordance with the Engineer's approval – high quality grey cast iron (as per ASTN A48/GG25) or soft steel is recommended. The bearing shells must be sealed against water or dust.

The bearing lubrication system and the cooling system must be chosen for the operating conditions and must be able to run continuously as the temperature in each bearing shell does not exceed 70°C, while the ambient temperature can reach 40°C. The lubricant layout shall be designed in such a way as to avoid any contamination of the pumped fluid.

All the bearings incorporated in the gearing sets shall be anti-friction, with a minimum lifespan of 100,000 hours (based on the relevant ASTM standard)

G.26.2 Below Water Bearings

The Contractor shall select the most appropriate type of bearing for the Plant being supplied.

Equipment with vertical shafts shall have thrust and guide bearings. All bearings shall be designed to exclude the ingress of dust and water.

Sealed for life units are acceptable subject to a minimum design life of 50,000 hours operation at maximum loading.

Plant which may be subject to vibration whilst stationary shall be provided with bearings designed to withstand damage from such a cause.

Below water bearings shall be of the journal type, of ferrobestos, gunmetal or equivalent and journals of stainless steel.

G.26.3 Above Water Bearings

Single journal plain bearings shall be phosphor bronze or synthetic lubrication impregnated bushes with carbon or stainless steel journals respectively. Synthetic bearings shall only be used where bearing condition can be inspected readily.

Plain type bearings shall be self-lubricating by grease, forced oil or impregnation.

Ball and roller type bearings shall be adequately lubricated by oil or grease and sealed to prevent leakage of lubricant along the shaft. Attention shall be given to ensure the dismantling of bearings is simple and free from risk of damage.

Bearings fitted to gear boxes shall a minimum design life of 100,000 hours at maximum loading.

G.27 Gearboxes

Where driven plant requires a drive system incorporating a speed reducing or increasing gearbox, the drive system shall be supplied by the driven plant manufacturer.

The gear form shall be in accordance with the relevant ISO or AGMA standard and for case hardened gears the depth of case shall be not less than 0.4 mm after profile grinding to counteract distortion. The gear load carrying capacity for strength and wear shall be determined in accordance with the relevant ISO or AGMA standard but the following parameters shall be taken as a minimum.

24 hours per day operation

Service factor of 1.4 based on the rated output of the respective prime mover.

Rated life of 100,000 hours

The gearboxes shall be totally enclosed, robustly constructed and suitable for continuous and arduous duty. The gears shall be enclosed in a cast or fabricated case. Fabricated steel cases shall be stress relieved prior to final machining. The case shall be split or provided with covers to facilitate inspection of the gears without dismantling the shafts. They shall incorporate ball and/or roller bearings. Taper roller bearings shall be incorporated in the gearbox when thrust loads are to be sustained.

Gear wheels shall be of high grade alloy steel, precision hobbed, hardened and ground to a high accuracy to ensure smooth running and optimum service life.

Input and output shafts shall be adequately sealed to retain lubricant and prevent ingress of contaminants under all operating conditions.

Shaft bearings shall be selected with a rated life of 100,000 hours at the maximum speed and power rating of the gears. Any end thrust from the gears shall be accommodated by the shaft bearings.

Long life seals on the input and output shafts shall be fitted up to prevent the escape of lubricant and the ingress of dust, sand and moisture.

Breather holes and/or pipes shall be sealed to prevent ingress of lubricant contaminants. Extension tubes also will be provided to facilitate filling and draining where is necessary. Breathers shall be provided with filters to prevent ingress of dust and moisture etc.

Oil level sight glasses fully protected shall be provided with levels marked for running and filling, minimum and maximum positions respectively. These shall be arranged for easy viewing.

Oil filling caps and oil drain plugs shall be provided. Oil level sight glasses shall not be provided for gears transmitting torques less than 10 kW.

Lubrication of bearings, etc, shall be by either splash or forced feed system.

The Contractor shall ensure that the lubricant used for the initial filling and specified in the maintenance manual is adequate for prolonged operation in ambient temperatures of up to 55°C without overheating.

Cooling may be by convection from the gearbox casings but without assistance from cooling fins or fans. Adequate other cooling means shall be provided as applicable. The exterior of the gearbox shall be free from dust or moisture traps.

Access for inspection purposes shall be allowed for in the design of the gearbox casing.

The gearboxes shall carry the manufacturer's identification details together with the rated shaft speeds, output power and maximum ambient temperature.

The gearboxes shall conform to the relevant applicable standards with respect to the following requirements:

The design ambient shall be -10°C to 42°C.

The noise at 120% of the full output power and 42°C ambient shall not exceed 80 dB A.

The gearings shall give double the life of the bearings when they are subjected to similar to the above conditions.

Each gearbox shall be equipped with an embossed nameplate including at least the following information:

- a) Manufacturer's name b) Gearbox type reference c) Serial or Order Number d) Power rating of gears e) speed ratio f) Lubrication specification (type and viscosity).

G.28 Flexible Couplings

Flexible couplings where supplied, shall be generously rated to cover the full range of duty. Couplings liable to impregnation by oil shall be of the all metal flexible type.

General Service couplings shall be of the flexible multi-pin and bush type, having not less than six bushes and each bush shall have an inner sleeve to allow rotation on the pin (bushes shall not be in direct contact with the pin). All pins shall have shoulders to allow positive location and securing to the bosses.

Bosses shall be a tight fit on the shafts and secured with hand fitted keys.

Couplings shall be supplied in matching balanced sets and shall be machined, balanced and marked before leaving manufacturer's works.

G.29 Strainers

Strainers shall be flange mounted type. Foot strainers shall be installed at least 0.5m (or as directed by the Engineer) above the bottom of the water reservoirs. The strainer basket shall be of the perforated cylinder type made from galvanized steel or stainless steel. It shall be easily accessible via a removable flange.

Also inline strainers shall be installed upstream the flow and water meters.

G.30 Safety Guards

All sections of the plant which constitute a safety hazard shall be covered by substantial guards or barriers.

All parts that in normal working are hotter than 60°C or colder than -5°C shall either be adequately fenced or shall be lagged.

All live electrical conductors, including conductors forming part of electrical apparatus, shall be either insulated or so fenced or placed as to prevent danger.

Machinery shall be correctly guarded to prevent staff injury and to comply with actual security norms, according to EN 953 + A1:2009.

Machinery shall be effectively guarded to prevent injury to persons, and meet current European safety regulations or equivalent Local Standards or other.

Adequate guards shall be supplied and installed throughout the installation to cover drive mechanisms.

All rotating and reciprocating parts, drive belts, etc. shall be securely shrouded to the satisfaction of the Engineer to ensure the complete safety for both maintenance and operating personnel. However, whilst all such guards shall be of adequate and substantial construction they shall also be readily removable for gaining access to the plant without the need for first removing or displacing any major item of plant.

Guards to parts of machinery which require regular inspection or maintenance shall be constructed of galvanised steel mesh or other corrosion resistant material which enables the parts to be examined and shall be attached in such a way as

to permit easy removal and replacement. All mild steel used in the construction of guards, including bolts, nuts, washers and brackets shall be hot dip galvanized unless otherwise specified.

Guards shall be attached by means of set bolts or studs in tapped holes. Self tapping screws shall not be used.

Where hinged access covers or doors are provided in covers or guards, they shall be interlocked with the electricity supply so as to prevent the operation of the machinery except when covers are in position and fixed. Warning notices labelled 'Danger - This plant may start automatically', shall be fitted to Plant and translated to Local language.

Safety signs are required for all hazardous plant areas.

The signs shall be of durable quality and shall comprise a substrate of 22 gauge aluminium, pre-drilled for fixing and with radiussed corners free of burrs or sharp edges. Symbols and lettering shall be screen printed. Drawings of safety guards shall be submitted to the Engineer for approval before manufacture

G.31 Setting Of Machinery

G.31.1 Foundations Builders Facilities and Setting of Machinery

The Contractor shall ensure that the positions of foundations for machinery plinths, holding – down bolts and the setting of machinery are positioned in accordance with the approved machinery drawings.

The Contractor shall, upon receipt of the necessary approved drawings for the machinery, carry out excavation work and the construction of all the necessary foundations and bases for the various items of plant, including the forming of holes and chases for pipework, steelworks, cabling, conduit, ragbolts and where necessary, the building in of foundation bolts and sundry items of plant, all in accordance with the drawings. Spaces shall be left between the concrete and bedplates etc. for grouting and building in.

The Contractor shall provide all necessary templates for fixing the positions of bolt holes, etc.

Anchoring screws should not be used at less than 100mm from concrete edge. These shall be mounted according to manufacturer's instructions. The anchoring screws shall be of stainless steel.

Except in special cases - e.g. where Plant is mounted on anti-vibration mounts or where special arrangements need to be made to ensure water tightness, items of plant shall be securely fixed and aligned on a common base plate. This base plate or frame shall be levelled, aligned and secured before grouting in.

Only one assembly work, of selected thickness, shall be used at each location of each anchoring screw. No more than two adjusting fittings shall be used at each location and each fitting shall be less than 3 mm thick.

The machinery shall be aligned, levelled and pulled down by the nuts of the holding down bolts with a spanner of normal length, and no grout shall be applied until the machinery has been run and checked by the Engineer for stability and vibration.

Where separate items of plant such as motors, couplings, gearboxes and similar items depend upon correct alignment for satisfactory operation, then each and every item shall be positively located in its correct operational position by means of dowels, locating pins, fitted bolts or other approved means to ensure that correct re-alignment can be easily achieved when re – assembling the items after removal for overhauls.

The Contractor shall clean the concrete and grout up after the pumps, motors, girders, etc. have been finally fixed and packed up.

Cementing of anchor screws shall be allowed only with written approval of the Supervision Consultant and shall be made before the machinery is laid. The final cementing of adjustment fittings shall be made only after the Engineer supervised an experimental operation for vibration study and only after the area to be cemented is clean and suitable for a proper application.

G.31.2 Alignment

Machinery bedplate design, packing and fixing shall be such as to minimize distortion and vibration. Aligned machinery shall be mounted on bed or sole plates, permitting removal and reinstatement without a requirement to re-grout. Bedplates shall incorporate fine adjustment of the vertical and horizontal alignment between driver and driven members.

All machinery shall be fitted with lifting facilities. Large structures shall be provided with jacking points.

Tapped holes or other provision must be made in all main castings, for the insertion of jacking screws or the fixing of drawing gear to facilitate dismantling on items of machinery subject to frequent dismantling. Bolts or studs shall be employed in preference to set screws.

G.31.3 Lifting

The machinery must be equipped with permanent lifting installations. The large structures must be fitted with travelling cranes or monorails as the case may be.

The pulleys, cranes, etc. shall be manufactured and tested according to appropriate European standards or other equivalent standards. The load tests shall be performed both at the manufacturer's location and at the place of installation.

The Contractor shall provide all the test weights and cables.

The pulleys and cranes shall necessarily be equipped with:

The guide rails with hoists and pulley stops and all the necessary accessories;

The guide rails and ramps, including the accessories necessary for the concrete piece and stops mounted on the rails.

The pulleys and cranes may be ordered from the ground level. They shall be equipped with all safety devices and, in the case of pulleys attached to a mobile hoist; the upper hooks shall be fitted with locking safety devices.

The existing lifting equipment shall be checked and, if necessary, modified to match these specifications.

G.31.4 Dismantling

The Contractor shall draw up and send the Supervision Consultant a performance technology for each moved machine, demolished foundation, maintenance procedure, protective measure for the existing machinery which shall not be moved, for approval purposes.

The pipes which shall be removed from service in the demolished areas shall be disconnected and shielded with concrete at the free ends along a length of 1 m and the related manholes shall be demolished up to 1 m below the ground level and filled with sand.

The surplus resulting from the demolition works shall be removed from the site to a location indicated by the Beneficiary or as stated in the Special Technical Specifications.

All the demolition works or the works for removing the machinery and disposing of it shall be in accordance with the national and local regulations for contaminated or hazardous materials.

G.32 Plant Identification

All pipe work equipment, panels and valves shall be identified. Pipe work shall be painted or colour banded and labelled. Adhesive labels shall be used to identify tanks. Equipment shall be identified using engraved plates of a non-corrodible metal fixed on to the item using four screws. Engraved tags of a non-corrodible metal shall be used for valve identification. Tags shall of a uniform shape and shall be fastened by a jack chain.

G.33 Penstocks, Valves, And Electrical Actuators

G.33.1 General Requirements

- The equipment described below and all described components and all its related parts and accessories shall comply to one of the International Standards Institutes requirements (i.e. EN, ISO, BSS, DIN, etc...).
- Manufacturer(s) must have the Label of Quality ISO 9001 to be qualified as supplier. The contractor shall not submit any materials for approval if not compatible with the required specifications and from an approved manufacture.
- Exercise proper care in the handling of work so as not to injure the finished surfaces, and take proper precautions to protect the work from damage after it is in place.
- The valves shall be designed to meet the operational and environmental conditions as specified in the Technical Specifications. Those that are to be used in the water, gas, air or oil systems shall be used as specified in detail for the application. Unless otherwise specified, the valves shall be provided to match the maximum work pressure, including all pressure peak values.
- The metal valves to be fitted in the plant shall comply with the provisions of EN 558 (Face-to-face dimension).
- The valves shall be complete with mounting flanges, in accordance with EN 1092.
- Unless otherwise specified, all the valves shall have double flanges subject to the operation pressure standards.
- All the valves, rods and hand wheels shall be positioned in such a way as to allow easy access of the operating staff. It shall be possible to remove, replace or repair the seats, seals, etc. that shall be accessible without removing the valve from the pipes or in the case of electrical valves, without removing the servo drive.
- The extension rods shall be provided wherever it is necessary to meet the specific operating requirements.
- The valves installed in underground rooms, where the access to a hand wheel is not practical, shall be operated with the extension rods and/or specific wrenches.
- The control mechanisms for all the valves and penstocks shall be executed so that they might be opened and closed by a single man in relation to a pressure 15% more than the maximum specified operating value. Any mechanism shall be designed so as to allow the manual operation in due time and not to exceed a requested pulling force of 250N. If necessary, gear sets shall be provided to ensure the maximum manual application force of 250 N over the edge of the wheel.
- The electrically operated valves shall include equipment for manual operation using a hand wheel or other suitable devices that shall be interrelated with the electric drive unit and secured onto it.
- In the case of electric valves, the handling devices shall be pre-assembled in the factory and tested.
- The manually operated valves shall be provided with a hand wheel made of cast iron or with a rod. The moving direction of the hand wheel shall be clockwise to close the valve and shall be marked on the hand wheel.

- The valves shall be fitted with closed-open position indicators and, if applicable, with light indicators for such positions.
- The Contractor shall submit a quality certificate showing that the valves have been loaded in accordance with ISC 9003 and EN 29003 and showing the pressures and the environment in which the test was conducted.
- Each valve shall have the following engraved on its body: the manufacturer's name, the year of manufacture, the nominal diameter, the rated pressure, the standard of conformity and an arrow indicating the direction of flow of the liquid flow rate. Those which are used as part of process equipment shall also have a yellow metal identification plate and a brief description of their function.
- The valves shall be primed and painted in the factory. Along with them, sufficient quantities shall be delivered to be able to redo the primer and paint coat, if need be.
- Those used for carrying drinking water shall be subjected to technical approvals and accepted by the Ministry of Health.
- The building materials (body, cover, inner parts, screws, gaskets, etc.) must withstand normal and maximum working conditions of the plant including them (pressure, temperature). Notice: For all existing check, gate, butterfly and surge relief valves that are installed on the pump discharge of the Raw water Intake pumps, High Service Lift pump and Intermediate pumps, the Contractor shall provide identical in all

respect to the existing valves. This is for the benefit of the water treatment plant regarding its overall performance, maintenance and spare parts acquisition.

G.33.2 Penstocks

Penstocks can be of the following types:

- i) Cast Iron with non ferrous polished sealed surface
- ii) Cast Iron with rubber sealed surface
- iii) Stainless Steel
- iv) Plastic covered steel penstocks

The type and size of the penstocks that are going to be used for various purposes will be as specified in the special technical specifications.

The frames, doors, sealing loads and shafts of all kinds of penstocks will be as specified in the articles herein.

Unless otherwise stated, every penstock will have a suitable hand wheel for its purpose and the reducers will be provided so that not more than 250 N of power will be necessary for operating the gear. The height of the hand wheel will be 1m above the working platform unless otherwise specified.

Hand wheels will bear cast marks on them indicating the opening and closing directions. Damage and weather resistant smooth polycarbonate pipes will be fixed for the protection of ascending shafts. Each pipe will be scratch marked for indicating the position of the penstock clearly and permanently.

The shafts will bear solid, trapezoidal or square section threads that are machined. These will be made of stainless steel or manganese steel or aluminum bronze. Extension shaft couplings will be of "muff" type, holes will be punched on these couplings and penstock shaft heads, and the shaft will be fixed on the shaft head by nuts and bolts.

If the extension shafts are installed in a fashion that they may be commanded from elevated ground level, shaft guides or guide clamps will be placed near the ground level. The distance between the shaft guides will not exceed 2.5m.

All hand wheels, operating mechanisms, foot clamps and guide clamps will be made of cast iron. Supporting pipes will be cast iron.

Fasteners and nuts that are to be provided from the manufacturer will be made of Stainless steel A4 according to ISO 3506. All penstocks will have raising shafts and will be operated by hand wheels or actuator gears. For (square or circular) penstocks of 300 mm and over, and for all motor and actuator operated penstocks, the support pipes will be placed between the penstock frame and the operating mechanism so as to compensate the loads in both directions. The pushing rods will contain all connection clamps and shaft guide plates.

Foot clamps and operating mechanisms will be provided especially at the locations that it is specified as necessary. Moreover, guide clamps will be provided wherever necessary. Pushing rings will be installed on the shafts and these shafts will be configured to transfer the pushing power of the valve directly to the valve body. Where an operating mechanism is requested, these will have a penstock position indicator.

The penstocks will be water tight under the operating pressure and flow direction conditions at the specific operation point (on seating and off seating). The allowed leakage from the sealing area will not exceed the requirements of DIN 19569-4 and especially:

- Channel Penstocks (sealing from 3 sides) with a maximum leakage rate of 6 L /min per linear meter of sealed perimeter, under water.
- Wall mounting (sealing from 4 sides) with a maximum leakage rate of 3 L /min per linear meter of sealed perimeter, under water All material used in the manufacturing of the penstocks will be of the minimum following standards:

* Cast Iron BS 1452 Class 180

* Bronze BS 1400 Class LG2

* Stainless Steel BS 970 Part 4 Class 316 S31

* Manganese Steel BS 970 Part 4 Class 150 M 19

* Phosphors Bronze BS 2874 Class PB 102

For the maintenance of the actuators that operate the sliding door penstocks and for manually operating of the actuators and the manual doors, maintenance platforms of St 37 material will be provided with the penstocks.

G.33.2.1 Cast Iron Penstocks

The frames and doors of the cast iron penstocks will be made of fine grain grey iron. The design of the penstocks shall enable closure, on the other hand the doors will be able to move freely during operation and the sliding wear on the tight surfaces will be the minimum. The penstocks will employ corrosion resistant adjustable wedges or rotating cams and operating arms.

The non ferrous tight surfaces will be formed by the installation of the exact size bronze or bronze tapes to the machined beds and fixing by corrosion resistant screws. The tape surfaces will be hand polished at the operating position until water tightness is achieved.

The cover nut will be bronze.

G.33.2.2 Stainless Steel Penstocks

The frames, guides and door frames of the penstocks shall be stainless steel BS 970 (AISI 316L) Class 316S13. Shaft guards shall be present around the raising shafts.

Penstock doors will be stainless steel, the shafts will be compliant to AISI 329 or similar standard 25% Cr, 4.5% Ni, 1.3% Mo alloy stainless steel.

The sealant metal surfaces shall be machined bronze or bronze tapes. The nuts of non raising shaft penstock doors will be bronze.

G.33.2.3 Plastic Covered Steel Penstocks

The frames of the plastic covered steel penstocks shall be of continuously welded mild steel, corrosion resistant. The frames will be bolted for easy lifting and will be profiled rigidly without any connection to the bridge and will be reinforced.

The doors of the plastic coated steel penstocks will be made by putting in approved rigid cellular polymer plates. These coatings will not contain carcinogenic asbestos etc material.

The linear thermal expansion coefficient of the material will not be greater than 1.6×10^{-5} for every C, and PVC or CTP material shall not be used. These doors will be structurally able to perform under desired pressures without deformation or distortions that may cause malfunctions or leaks. If necessary, they will be framed by steel matrices of enough rigidity.

Sealant surfaces and edge guides will be from wear resistant plastic tapes that have a friction coefficient smaller than 0.10.

Moreover it shall be approved by the engineer. The gasket tapes will be safely fixed in the inner surface of the frame. Adjustment equipment and other devices will be provided for ensuring free movement without loss in the sealing level. Adjustment devices will be made from stainless steel or other corrosion resistant material, at the same time they will be easily replaceable.

Shaft operating nuts shall be red or approved ultra high molecular weight polyethylene material. For non raising shafts, operating nuts or the shaft fixing blocks of the raising shafts will be mounted on a separate door lifting kennet visibly by stainless steel connections. Operating nut or the shaft fixing block shall not stay in the door.

All the nuts and bolts used in the manufacture and mounting of the penstocks shall be stainless steel.

All plastic material will be non toxic and UV stabilized and will be fire resistant as per BS 476, compliant with classes "P" and "I" of Parts 5 and 7.

The materials that are to be used in the manufacture of the plastic covered steel penstocks that are going to be used for purified or non purified water considered as potable shall be evaluated by and obtained an approval certificate from the British Water Research Center or a similar institution.

G.33.2.4 Manufacturer's Instructions

Compliance: Comply with manufacturer's product data, including technical bulletins, product catalogue installation instructions.

G.33.2.5 Examination

Examine the pits to receive the penstocks. Notify the Engineer of conditions that would adversely affect installation or subsequent utilization and maintenance of the penstocks. Do not proceed with installation until unsatisfactory conditions are corrected.

Penstocks shall be operated from fully closed to fully open positions to verify correct operation. For penstocks fitted with power-operated mechanism, the test shall be carried out to demonstrate correct manual and power operation.

A leakage test shall be carried out to prove the penstock is drop tight under seating and unseating conditions.

G.33.2.6 Installation

The installation of the penstock will be performed in a professional manner and in accordance with the manufacturer's instructions. It is the responsibility of the installer to handle, store and install the penstock in strict compliance with the manufacturer's instructions, drawings and recommendations.

Before installation: Before the installation of the penstocks it is necessary to check that the material supplied conforms to the order placed and matches the model and serial number assigned.

The damper assembly is provided in different parts:

Gate fitting and attached to the frame together with a spindle.

Extension of the spindle and wall brackets if any.

Actuator and ground anchor.

Once the mechanical and dimensional checks have been carried out, cover again with the protections for transportation and storage it is supplied with, in order to keep the penstock free from dirt during installation.

To ensure correct installation, commissioning and maintenance of penstocks, an area free from obstacles must be available in case it is necessary to remove any components thereof, as well as to carry out repair and replacement tasks of any of the damaged components.

G.33.3 Actuators

G.33.3.1 Electric Actuators

Where required penstocks and valves shall be operated by means of electrically driven actuators with integral reversing starters. Each actuator shall be sized to produce at least 150% of the torque requirement quoted by the valve or penstock manufacturer. Valve actuators shall have an index of protection rating IP 67 or above and have totally enclosed drive units and reduction gearing. Each actuator shall be provided with an integral control and starter system allowing local and remote operation, control and indication. Control systems shall include facilities for valve modulation using a 4-20 mA control signal. The actuators shall also have the facility for hand operation, the use of which shall automatically disengage the electric motor. The hand operation facility shall be capable of being padlocked in the inoperative state. Limit switches and torque limiting devices shall be incorporated to prevent over running.

Each actuator drive unit shall be complete with integral starter, anti-condensation heater, local operating buttons, and local and remote selector switch, all to be housed in an IP67 enclosure suitable for accepting mechanical cable glands for incoming power and control cables. Facilities for the operation of remote indicating lights and control signals, etc. shall be fitted.

A phase discriminator and monitor relay shall be provided.

The actuator shall have volt free contacts to indicate when the valve is fully open, fully closed or has failed.

The electrical supply available is 380 volts, 3 phases, 4 wire 50 Hz, and the unit shall incorporate a 380/220 to 110 volts transformer for control circuits.

Each actuator shall be adequately sized to suit the application and be continuously rated to suit the modulating control required. The operating gear of all penstocks shall be capable of opening or closing the gate against an unbalanced head equal to the maximum working pressure.

The gearbox shall be oil or grease filled, and capable of installation in any position. Alternative hand operation shall be possible, and the hand wheel together with a suitable reduction gearbox if necessary, shall be of adequate dimensions for easy operation by two men.

The motor drive shall be automatically disengaged when under manual operation. Hand wheels shall be rotated clockwise to close the valves, and shall be clearly marked with the words "OPEN" and "CLOSE" and arrows in the appropriate directions. The rims of hand wheels shall have a smooth finish.

All actuators with the exception of rising spindle penstocks shall be equipped with indicators showing whether the penstock is fully open or closed. A transparent PVC cover shall be fitted to protect the thread of the rising spindle. All operating spindles, gears and headstocks shall be provided with adequate points for lubrication.

Penstocks will be equipped by electrical actuators that contain integrated direction change drives where necessary.

Each actuator will be weather proof and will be equipped by condensation preventing heaters, up and bottom limit switches and torque switches. All local controls will be under a lockable cover.

The existing power line is 380 volt; three phases, 4 lines 50 Hz. and the unit will contain a 380/220-110 volt transformer for the control circuits.

Each actuator should have suitable dimensions for its purpose and will be able to work continuously for adapting to the required modulated control. The drive mechanisms of all penstocks will be able to open and close the gates under a load differential equal to the maximum operating pressure.

The gear box will be filled with oil or grease and will be able to be installed in any position.

The hand wheel will be turning clockwise for closing the gates and the opening and closing directions will be clearly marked with arrows and phrases (On/Open) and (Off/Closed). The surfaces of the hand wheels will be smooth.

All drives other than raising shaft penstocks shall have indicators that show if the penstock is fully open or fully closed. Transparent polycarbonate guards will be installed for protecting the threads of the raising shafts.

Suitable lubrication points shall be provided for all drive shafts, gears and lifting mechanisms.

G.33.3.2 Pneumatic Actuators

Where required valves shall be operated by means of pneumatic driven actuators. Each actuator shall be sized to produce at least 150% of the torque requirement quoted by the valve manufacturer. Control systems shall include facilities for valve modulation using a 4-20 mA control signal.

The actuator shall have volt free contacts to indicate when the valve is fully open, fully closed or has failed.

The type of actuator will be such as: Pneumatic twin piston actuator, with installed solenoid valve 5/2 for ON – OFF operation.

System design Pneumatic twin piston actuator-double-acting Construction features Rack-and-pinion technique with self-centering piston guidance in casing; Installation position Random Standards Interface actuator/valve: Four or eight female threads in the casing acc. to DIN EN ISO 5211. Interface actuator/control valve /signal units: Acc. to VDI/VDE 3845 (NAMUR)

Materials Casing: anodized aluminium alloy Caps: aluminium alloy epoxy coated, type or plastics, epoxy lacquered Piston/ aluminium alloy, toothed rack: aluminium alloy, or plastics Shaft: steel, hard nickel plated Gaskets: NBR (buna N) Bearings: easy sliding plastics

Ambient temperature - 20 up to + 95°C

Nominal pivoting angle Double-acting: 90°, 120°, 180°, 240° Adjustable nominal pivoting angle from + 5 to – 5 °

Torques 3 to 8000 Nm

Control pressure 2 to 10 bar

Control medium/quality Filtered air; minimum requirements of DIN ISO 8573-1/ class 4 apply for residual oil, dust and water content

G.33.4 Butterfly Valves

Butterfly valves, manual or motorized, fitted with maintenance free worm gear including mechanical position indicator and hand wheel; other combined gear type may be used for specified application if particular min number of turns is specified. Where required, valves shall be electrically actuated with a manual override.

- Butterfly valves shall comply with EN 593 + A1: 2011 and shall be adequate for mounting in any position.
- Butterfly valves shall be of double flanged pattern, with ductile cast iron body or other material approved by the Supervision Consultant and shall be for closed-open position.
- Valves, which are to operate in throttled positions, shall be metal seated. Leakage rates shall not be greater than Rate D for low leakage valve application, as referred to in EN 593 + A1: 2011. For all other duties, butterfly valves shall be of the resilient seated type and shall be airtight when shut off at all operating pressures. Seat materials shall be suitable for use in contact with potable water or wastewater as appropriate.
- The disc shall be in grey or ductile cast iron with a resilient seating ring in moulded rubber, or other material to the consent of the Engineer, located in a landing on the disc and secured by a gunmetal retaining ring fixed with screws made from homogenous corrosion-resistant material.
- Valve shaft shall be machined from Stainless Steel while steel bearings shall have active surface from PTFE or other materials approved by the Engineer.
- The shaft may be in one piece or attached as two stub ends on opposite sides of the disc. Grub screws, pins (parallel or taper) or clamps will not be acceptable.
- The shaft shall rotate in bearing bushes fitted with grease lubrication facilities.
- Glands shall be of the double O-ring type and shall be fitted on the operational shaft extension to seal the pressure side of the valve. The design shall be such as to facilitate O-rings replacement without removal of the valve from the pipeline.
- The valves shall be protected inside and outside by epoxy powder coatings.

Butterfly Valves for diameters above DN300: Resilient – seated, double eccentric offset flange butterfly valve EN 593 with DIN DVGW-Type Test Certificate for drinking water (PN 10- PN 16) DN 150- DN 1600, PN 10- PN 40.

Face-to-face dimension DIN EN 558, Series 14 (F4)

Valve disc shall be with double eccentric offset, support in body in maintenance-free bushes.

Also, valve disc and shaft shall be of polygonal-connection, free of play and un-notched.

The closed disc eye has to be without additional locking elements.

Shaft should be encapsulated by sealed bearing bushes, shaft and shaft seal with anti-blow out design, suitable for vacuum.

Robust and maintenance-free slider crank mechanism gear box with adapted torque transmission, self locking in closing direction, protection degree IP68, integrated position indicator, for motorized valves.

Profile seat at the disc shall be adjustable and replaceable, both sides tight.

Handling shall be either on mechanical (hand wheel, chain wheel, pneumatic, etc) or electric actuators.

- Flanges according to DIN 1092-2.
- Tightness according to DIN 12266-1, leak-rate A.
- Body and disc made shall be made of EN-GJS-400-15 (GGG 40).
- Valve seal shall be made of EPDM.
- Valve shaft shall be made of stainless steel grade 1.4021, QT800.
- Bolts in touch with the medium shall be made of stainless steel grade A2.
- Valve seat shall be made of corrosion-and shall wear resistant chromium-nickel weld overlay.

G.33.5 Gate Valves

Flanged gate valve short DIN F4, for water and sewage to max. 70° C, designed according to DIN/EN, Face to face according to EN 558 table 2 basic series 14. Standard flanges drilling to EN1092-2 (ISO 7005-2). Hydraulic tests according to EN 1074-1 and 2 / EN 12266 has to determined.

Stem sealing with independent stem seals offering safety against dirt from outside, protection against galvanic corrosion and sealing acting as the main hydraulic seal to the flow.

The unique assembly of the valve body and bonnet ensures a durable tightness preventing it from being blown out by pressure surges. A stainless steel bonnet bolts are countersunk in the valve bonnet encircled by the bonnet gasket and sealed with hot melt. Thus there is no risk of corrosion as the bolts are not exposed to the medium or soil.

The fixed, integral wedge nut reduces the number of movable valve parts thus minimizing the risk of corrosion and malfunction. The wedge nut has to be made of dezincification resistant brass with lubricating abilities providing optimum compatibility with the stainless steel stem.

The ductile iron core has to be fully vulcanized with drinking water approved EPDM rubber internally and externally. No iron parts are exposed to the medium and the excellent rubber vulcanization prevents creeping corrosion underneath the rubber. Guides in the wedge and on the valve body ensure a uniform closure regardless of high pressure. Safe operation is ensured, as the guides prevent overloading of the stem. The wedge has a large through bore and as there are no hollows in the core, stagnant water or impurities cannot collect and cause contamination.

The Ductile Iron Gate valves should have the following characteristics:

- Resilient seated gate valve to EN 1074-1 and 2 / EN 1171.
- Working Pressure up to 40 kg/cm² (PN 6/10/16/25 and 40).
- Working Temperature: From – 10 °C up to 70 °C, resilient type Soft sealing for PN10 /16 /25, metal seated for PN25/40 and DN≥300
- Body and bonnet in spherical graphite ductile iron EN-GJS-400-15 (GGG-40) as a minimum, with blue Ral 5015 epoxy powder coating electro statically applied (EN1563) with min 250 microns. Preferable: Body and bonnet of GJS-500-7 (GGG-50)
- Wedge of ductile iron EN-GJS-400-15 (GGG-40), fully vulcanized by EPDM, or NBR rubber (DVGW). EN1563.

- Wedge lock nut in copper alloy with high resistance to corrosion, EN 12165
- Stem in stainless steel min. 13% Cr, AISI-420 (X20C13), EN 10080 Stem with rolled thread and wedge stop ring.
- Body-bonnet gasket in EPDM or NBR (DVGW), EN681-1. EPDM bonnet gasket in a groove, countersunk bonnet bolts encircled by the bonnet gasket and sealed with hot melt. Body-bonnet bolting in Stainless steel quality A4
- Gate valves are supplied with hand wheel in stamped steel or square cap in EN-GJS-400-15 (GGG-40) for 30x30 T-key. They can also be operated with gear-box, electric, pneumatic actuator, extensions, EN 10088 / EN1563.
- Epoxy coating to DIN 30677-2 internally and externally.
- Gate Valves should be tested according to EN 1074-1 and 2 / EN 12266, or BS 5163 part2. Seat: 1.1 x PN, Body: 1.5 x PN
- Third Party approval: product conformity certificate from Bureau VERITAS or similar in addition to a proof of suitability for drinking water.
- Dimensions : as per EN 558 table 2 basic series 14 or BS 5163 part1
- Flanges and drilling EN1092-2 (ISO 7005-2).

The Metal Seated Gate valve for DN>300 and PN 25 should be according to BS5163 & BS5150 and having the additional following characteristics:

Wedge in Ductile Iron, BS EN 1563 / EN-GJS 400/15.

Wedge Face Aluminum bronze, EN1982 CC331G.

Hydraulic test to BS 5150 / EN 1171, Seat: 1.1 x PN, Body: 1.5 x PN. For all valves types for DN>350mm bypasses are required.

G.33.6 Check Valves

G.33.6.1 General

Check valves shall comply with BS 5153 and be double flanged cast iron unless otherwise specified.

They shall be of the quick action single door type, designed to minimise slam on closure by means of heavy gunmetal-faced doors weighted as necessary. The valves shall be fitted with positively fixed renewable gunmetal door sealing faces.

The door hinge pin/shaft shall extend through a sealing gland on the side of the body, and be fitted with an external lever to permit back flushing. Glands shall be of the 'O' ring type.

The valve door shall be weighted to suit the application and the lever shall be of the heavy duty type designed for the addition of external weights, should these be required at some future date.

All check valves shall be suitable for operating in the horizontal plane unless otherwise specified.

Covers shall be provided to allow ample access for cleaning and service and shall be supplied complete with tapped bosses fitted with air release cocks.

Valves above 350 mm bore shall be provided with feet.

The design of the valve body shall be such that there is adequate clearance around and at the back of the door to minimise jamming by rags or debris. Stops shall be provided to limit the back lift of the door; these shall be positioned to prevent fouling.

The hinge pin/shaft shall be stainless steel and preferable square in section, to ensure positive location of the door. If circular shafts are utilised, the back flushing lever shall be located on a squared section, the diagonal dimension of which shall be equivalent to the full diameter of the shaft. Both door and lever shall be positively and securely fixed to the hinge pin/shaft. Grub screws, pins (parallel or taper) or clamps will not be acceptable. All internal fixing devices shall be of stainless steel.

Valves shall carry identification marks and/or plates in accordance with BS 5153.

Valves shall be sized, such that the velocity through the valve when fully open does not exceed 2.25 metres per second at the rated throughput. They shall have flanges to BS 4504 NP 16 and shall be capable of withstanding the same test pressures as the pipeline on which they operate. All nuts and studs subject to vibration shall be fitted with spring washers or locking tabs unless otherwise specified.

G.33.7 Ball Check Valve

Ball-type check valve shall be: Face-to-face dimension to EN 558, Series 48. Flange connection dimensions to EN 1092-2

Manufacturer shall have a quality management system that is certified to ISO 9001 by an accredited, certifying body.

The ball check valve shall be designed so as the closing ball being in open position shall be pressed out from the flow cross-sectional area by the medium. This opens the valve.

Ball check valves are therefore especially suitable for wastewaters posing a high risk of clogging. When in open position, the ball check valve shall have a low flow resistance. It shall not have any mechanically moved parts making it extremely maintenance friendly. Also, it shall be insensitive to dirt and therefore suitable especially for use in wastewater.

Body shall be made from lamellar graphite cast iron EN-JL1040.

Cover shall be made from spheroidal graphite cast iron EN-JS1030.

The sealing ball shall consist of an NBR rubberised steel ball.

Connecting bolts A2.

Corrosion protection of the body parts:

Epoxy resin powder coating inside and outside, colour blue, coat thickness: min. 250 µm

All valves shall be hydrostatically tested and seat tested to demonstrate zero leakage. The manufacturer shall provide test certificates, dimensional drawings, parts list drawings, and operation and maintenance manuals.

The exterior and interior of the valve shall be coated with an ANSI/NSF 61 approved fusion bonded epoxy coating.

G.33.8 Tilting Disc Check Valve

Check valve with weight lever shall be:

Face-to-face dimension EN 558, Series 14

DN 200 to DN 1400, PN 10

DN 150 to DN 1000, PN 16

DN 150 to DN 700, PN 25

Flanged connection dimensions to EN 1092

Manufacturer shall have a quality management system that is certified to ISO 9001 by an accredited, certifying body.

The tilting-disc check valve is the valve disc which shall have a freely oscillating, flow-facilitating design with double eccentricity support. The shafts shall be equipped with in maintenance-free, self-lubricating friction bearings, and the shaft has maintenance-free seals. A rolled up, solid body seat ring made of stainless steel, and a disc seat ring which is additionally provided with an elastic fine seal, provide perfect sealing. The tilting disc check valve's shaft shall be with smooth, easy-moving support in the flange bearing in maintenance-free bushings.

Valve disc and shaft shall be fixed with robust keyed connection. It shall have double shaft seal with O-rings supported in spacer. The valve disc shall have seat ring and fine elastomer seal. Stable fastening of the weight lever on the shaft is fitted with square socket.

Body, valve disc and flange bearing shall be made from EN-JS 1050

Seat in body and on the valve disc shall be made from stainless steel, 1.4057

Shaft shall be made from high-strength, stainless steel 1.4057

Bolts shall be made from A2

Seals shall be made from NBR

Corrosion protection of the body parts

Epoxy resin powder coating colour blue, inside and outside coat thickness: min. 250 µm, in accordance with DIN 30677-2

All valves shall be hydrostatically tested and seat tested to demonstrate zero leakage. The manufacturer shall provide test certificates, dimensional drawings, parts list drawings, and operation and maintenance manuals.

G.33.9 Non-Slam Nozzle Check Valve

Non-return nozzle valve, resilient-seated, soft-sealing with central valve disc

DN 80 – DN 300, PN 10 – PN 40

Face-to-face dimension EN 558, Basic line 14 and

Non-return nozzle valve, resilient-seated, soft-sealing with piston ring

DN 350 – DN 600, PN 10 – PN 16

Face-to-face dimension EN 558, Basic line 14.

Manufacturer shall have a quality management system that is certified to ISO 9001 by an accredited, certifying body.

- Valves shall be provided with flange connection dimensions to EN 1092.
- The non-return nozzle valve, resilient-seated, soft-sealing with central valve disc DN 80 – DN 300, PN 10 – PN 40 shall have:
 - One-piece body with flow-facilitating shape
 - Centrally guided valve disc by means of guide rod in body insert
 - Guide rod supported in corrosion-proof maintenance-free bushing
 - Body insert supported and secured, corrosion-proof, in the body

- Internal parts (valve disc and spring) are replaceable
- Valve disc rubberised
- Pressure loss at 2.0 m/s Flow velocity depending on nominal size approx. 13 mbar – 20 mbar
- Valve disc stop damping through elastomer on valve disc
- Non-return nozzle valve, resilient-seated, soft-sealing with piston ring DN 350 – DN 600, PN 10 – PN 16 shall have:
 - One-piece body with flow-facilitating shape
 - Non-centrally guided piston ring by means of guide rods in body insert
 - Guide rods supported in corrosion-proof maintenance-free bushing
 - Body insert supported and secured, corrosion-proof, in the body
 - Internal parts (piston ring and spring) are replaceable
 - Piston ring rubberised
 - Pressure loss at 2.0 m/s Flow velocity depending on nominal size approx. 24 mbar – 40 mbar
 - Piston ring stop damped
 - Body DN 80 – DN 125 (PN 10 – PN 40) shall be made from EN-JS1025
 - Body DN 150 – DN 300 (PN 10 – PN 16) shall be made from EN-JS1030
 - Body DN 150 – DN 300 (PN 25 – PN 40) shall be made from EN-JS1025
 - Body insert and valve disc shall be made from zinc-free bronze
 - Bearing bushes in body insert shall be made from high-performance elastomer
 - Sealing profile on valve disc shall be made from EPDM with KTW and W 270
 - Guide rod and compression spring shall be made from stainless steel
- And
 - Body DN 350 – DN 400 (PN 10 – PN 16) made from EN-JS1030
 - Body DN 500 – DN 600 (PN 10 – PN 16) made from EN-JS1025
 - Body insert and valve disc made from zinc-free bronze
 - Bearing bushes in body insert made from high-performance elastomer
 - Sealing profile on piston ring made from EPDM with KTW and W 270
 - Guide rod and compression spring made from stainless steel
 - Corrosion protection of the body parts shall be:
 - Inside blue enamel, outside epoxy resin coating, blue or equivalent colour. All valves shall be hydrostatically tested and seat tested to demonstrate zero leakage. The manufacturer shall provide test certificates, dimensional drawings, parts list drawings, and operation and maintenance manuals.

G.33.10 Swing Check Valve

SWING Check valve shall be:

DN 200-300, PN 10

DN 50-300, PN 16

Face-to-face dimension EN 558, Series 48

Manufacturer shall have a quality management system that is certified to ISO 9001 by an accredited, certifying body.

Valves shall be provided with flange connection dimensions to EN 1092.

The Swing check valve shall be thereby scrapable in flow direction.

The ball-shaped bearing pin shall ensure self-centring of the valve disc in the body seat which always shall guarantee sealed closure, even at low back pressures.

The shaft shall be supported in the cover, thereby medium free, permanently smoothly running and shall easily be replaced.

Moreover, the valve shall be equipped with a basket guard to prevent accidents in the area of the lever.

A conversation of internal to external shaft with lever and weight shall also be done later without mounting the valve from the pipe.

Also, valve's shaft shall have smooth, easy -moving support in bushings in the cover possible opening at least 90% of DN

Stable fastening of the weight lever on the shaft with square socket with basket guard made from impact-resistant, transparent plastic within swivel range of lever and weight.

Body parts shall be made from GGG

Seat in body and shaft, valve lever and valve disc shall be made from stainless Cr steel.

Bolts shall be made from A2.

Fine seal in the valve disc shall be made from NBR

Shaft with double, maintenance-free seal shall be made from NBR.

Corrosion protection of the body parts: Inside and outside EKB, epoxy resin coating with "heavy-duty corrosion protection" design to DIN 30 677-2.

Coat thickness >250 µm.

All valves shall be hydrostatically tested and seat tested to demonstrate zero leakage. The manufacturer shall provide test certificates, dimensional drawings, parts list drawings, and operation and maintenance manuals.

G.33.11 Surge Buster Check Valve

This specification shall cover the design, manufacture, and testing of Surge buster Swing check Valves suitable for cold working pressures of 250 psig water service.

The check valve shall be of the full body type, with a domed access cover and only two moving parts, the flexible disc and the disc accelerator.

Valves shall be designed, manufactured and tested in accordance with American Water Works Association Standards ANSI/AWWA C508.

Manufacturer shall have a quality management system that is certified to ISO 9001 by an accredited, certifying body.

Valves shall be provided with flanges in accordance with ANSI B16.1, Class 125.

Valve body shall be full flow equal to nominal pipe diameter at all points through the valve. The seating surface shall be on a 45 degree angle to minimize disc travel. A threaded port with pipe plug shall be provided on the bottom of the valve to allow for field installation of a back flow actuator, air cushion or hydraulic cushion without special tools or removing the valve from the line.

The top access port shall be full size, allowing removal of the disc without removing the valve from the line. The access cover shall be domed in shape to provide flushing action over the disc. A threaded port with pipe plug shall be provided in the access cover to allow for field installation of a mechanical, disc position indicator.

The disc shall be of one-piece construction, precision molded with an integral O ring type sealing surface, and contain alloy steel and nylon reinforcement in the flexible hinge area. The flex portion of the disc shall be warranted for twenty-five years. Non-Slam dosing characteristics shall be provided through a short 35 degree disc stroke and a disc accelerator to provide a cracking pressure of 0.3 psig.

The disc accelerator shall be of one piece construction and provide rapid closure of the valve in high head applications. The disc accelerator shall be enclosed within the valve and shall be field adjustable and replaceable without removal of the valve from the line. The disc accelerator shall be securely held in place by being captured between the cover and disc. It shall be formed with a large radius to allow smooth movement over the disc surface.

The valve disc shall be cycle tested 1,000,000 times in accordance with AN51/AWWA (SOB and show no signs of wear, cracking, or distortion to the valve disc or seat and shall remain drop tight at both high and low pressures. The test results shall be independently certified.

The valve body and cover shall be constructed of ASTM A536 Grade 65-45-12 ductile iron or ASTM A126 Class.

The disc shall be precision molded Buna -N (NBR), ASTM D2000-BG.

The disc accelerator shall be type 302 stainless steel.

ADDITIONAL FEATURES A screw - type back flow actuator shall be provided to allow opening of the valve during no-flow conditions. Buna -N seals shall be used to seal the stainless steel stem in a bronze bushing. The backflow device shall be of the rising stem type to indicate position. A stainless steel T-handle shall be provided for ease of operation.

A mechanical indicator shall be provided to provide disc position indication. The indicator shall have continuous contact with the disc under all operating conditions to assure accurate disc position indication.

A pre-wired limit switch shall be provided to indicate open/ closed position to a remote location. The mechanical type limit switch shall be activated by the external position indicator.

A bottom mounted oil dashpot (oil cushion) shall be provided to provide hydraulic control of the final 10% of valve closure and reduce valve slam and water hammer normally associated with rapid flow reversal conditions on pump shut down. The dashpot shall consist of a high pressure hydraulic cylinder, adjustable external flow control valve, oil reservoir, pressure gauge, stainless steel air inlet valve, and piping designed to control the closing speed of the last 10% of travel in 1-5 seconds. A threaded brass dashpot bushing unit with a grease fitting for lubrication shall connect the cylinder to the valve and shall have an air gap to prevent hydraulic fluid from entering the valve and contaminating the water system. A snubber rod fitted with O-ring seals and rod wiper scrapers shall make contact with the lower portion of the disc's stainless steel strike plate.

MANUFACTURER AND MODEL The manufacturer shall demonstrate a minimum of five (5) years experience in the manufacture of resilient, flexible disc check valves with air and hydraulic cushions.

All valves shall be hydrostatically tested and seat tested to demonstrate zero leakage. The manufacturer shall provide test certificates, dimensional drawings, parts list drawings, and operation and maintenance manuals.

The exterior and interior of the valve shall be coated with an ANSI/NSF 61 approved fusion bonded epoxy coating.

Surge buster Swing Check Valves shall be Series # 7200 as manufactured by Val-Matic Valve & manufacturing Corporation, Elmhurst, IL. USA.

This valve is used at the Raw water Intake pumps discharge.

G.33.12 Ball Valves

Valves shall be bronze ball type with threaded ends, Teflon stem packing seals, Teflon seats, “ T “ handle for 25 mm and smaller, insulated operating lever for 30 mm and larger, and blowout proof silicone bronze stem.

G.33.13 Flap Valves

Flap valves shall be normally closed, by weight of the door only, and shall open under minimum flow conditions. They shall be capable of withstanding 1.5 times the specified maximum seating head.

Where flap valves are required for flange mounting, they shall be supplied with rubber gasket and the full number of holes to BS.4504 NP 16.

All flap valves shall be operated and painted in accordance with metal painting and protection requirements.

G.33.14 Dismantling Joints

All Dismantling Joints shall be tested in accordance with the requirements of NSF 61 and the American Water Works Association Standard C.219 for bolted couplings.

The Dismantling Joint shall be a self-contained flanged restrained joint fitting, including both flanged components and sufficient harness bars to withstand the imposed thrust. The Dismantling Joint shall allow for up to 2" of longitudinal adjustment. The pressure rating shall be determined by the flange configuration and all commonly used flanges shall be available. As standard, flanges to AWWA C207 Table D shall be used.

The Dismantling Joint shall be furnished as a complete assembly consisting of spigot piece, flange adapter, tie bars and gasket. The Dismantling Joint shall be designed so that no part of the restraint system extends outside the flange diameter. The internal bore shall match that of the pipe system.

The spigot piece shall be of steel to ASTM A283 Grade C. The Flange Adapter shall be ductile iron to ASTM A536 Grade 65-45-12. Tie bars shall be ASTM A193 Grade B7 threaded rod with rolled threads.

Gasket shall be EPDM Grade E. The Dismantling Joint shall be supplied with an in-house applied fusion bonded Epoxy or Rilsan Nylon coating applied by fluidized bed method. The coating shall comply with the requirements of NSF 61 and AWWA C550 as applicable.

The design pressure rating shall be equal to or greater than the mating flanges. The gasket seal and compression stud and nut arrangement shall be independent of the tie rod restraint system.

Tie Rod diameter shall be compatible with the corresponding bolt diameter of the mating flange. The Tie Rod restraint system shall be capable of withstanding the full pressure thrust that the pipe system can develop at no more than 50% of the yield strength of the tie rod material. The Dismantling Joint shall be as manufactured by Viking Johnson.

- Steel: To ASTM A283 Grade C

- Flange Adapter up to 12": Ductile Iron ASTM A536 Grade 65-45-12
- Flange Adapter above 12": Steel to ASTM A283 Grade C
- Tie bars: High Tensile Steel to ASTM A193 Grade B7
- Nuts: Heavy Hex to ASTM A194 Grade 2H
- Hardened Washers: to ASTM F436
- Gaskets: EPDM compound conforms to ASTM D2000. Suitable for raw and potable water
- Coating:
- Flange adapter and flange spigot: Rilsan Nylon 11.
- Tie Bars, nuts and washers: Zinc plated to ASTM B633 Type SC1.

G.33.15 Ball Float Valves

Ball float valves which are to be installed within reservoirs shall be of the delayed action type to eliminate inflow at small valve openings. They shall comply with B.S. 1212 and shall be fitted with a stilling chamber, auxiliary float valve and inlet bellmouth with regulating valve.

G.33.16 Cast Steel Valves

The cast steel valves shall be used where ductile iron valves are not permissible to operate at pressure > 25 bars, and shall comply to NF E 29-328, NF E29-331. The specifications of other valve parts shall be at least the same of the ones of ductile iron valves.

1. Hand wheel : in steel DIN 17100 or cast iron epoxy coated DIN 1691 2. Stem cap in cast iron DIN 1691 or ductile iron EN1563 3. Extension spindle : Mild steel ST3/ZN6 4. Operation keys: Combination prizing bar and lifting key tube, with 1.5 m vertical bar and 0.5 m horizontal bar.

G.33.17 Air-release Valves

Air-release valves, body and components shall comply to SG 400-15 ductile iron, and are to be installed as directed by the Engineer.

Air-release valves are introduced into the water main in order to eliminate air collections at high spots and changes in slopes.

Single air-release valves are meant to discharge the trapped air automatically under normal operating conditions, (when pipes are under pressure).

In addition to the role mentioned in paragraph a), double air-release valves (triple function air valves) permit bulk air vent under pressure, blowing off air when filling the pipes with water, and air ingress during emptying. They are also used at steep slopes to protect against sharp pressure drop in case of accidental breakage.

Air-release valves shall be supplied with an isolating valve which permits the complete removal of the air-release valve from the main without affecting the flow of water.

Air-release valve are mounted on a vertical branch connection with at the top of the main. Air-release valves shall operate automatically and shall be constructed in a manner that the operating mechanism will not jam in either position (open or close).

Air-release valves shall be of single orifice valves (SOV) for distribution networks, and of double orifice valves (DOV) for transmission lines, pumping lines, and inside reservoirs valve chambers.

G.33.18 Pressure Reducing Valves

The pressure reducing valves shall be of the spring loaded type and of an approved design with a single external hydraulic relay system to ensure a constant downstream pressure for a variable upstream pressure.

The main valve body, cover and internal valve shall be of cast iron. The liner shall be bronze to BS 2870. The indicator rod shall be of stainless steel to BS 970 with all other components being of appropriate non corroding materials.

The relay system body shall be in bronze as shall all control valves. All connection piping and internal fittings shall be in non corroding materials.

Each valve shall be subjected to a body pressure test in the manufacturers works and witnessed by the manufacturer accordingly.

The relay system shall be capable of being checked or replaced without breaking the supply.

G.33.19 Downstream Level Control Valve and Pressure Head Breaker

This valve is installed in order to fulfil both functions of:

- Adjusting the upstream pipeline flow rate with the downstream side consumed flow rate.
- Local energy dissipation.

The downstream level control and head breaker valve should be installed at the end of a pressure pipeline before discharging into a water basin. It should control the water level within the water basin, where it is installed, regardless of the flow variations. This valve should be of Self – Centering Disc Obturator type from Alstom or Hydrostec or equivalent.

The upstream pipeline is connected to a vertical orifice (nozzle) at its end, above which is placed a flat disc linked with an operating rod. When exposed to the jet of water, the disc centers itself even in the absence of any lateral guiding. Using a rocker arm, the disc is operated by a cylindrical float having a vertical axis; the float moves in a chamber communicated with the downstream reservoir.

The type of obturator to be used is the hooded disc obturator type – OBCA, where the orifice and disc are located above the water level to be controlled. The orifice is a sharp – lipped nozzle and the disc is flat. A completely watertight seal should be insured by a reinforced rubber lining on the underside of the disc. This valve should include the following accessories:

- Roker arm
- Bearing
- Swivel ring
- Self – centering disc
- Deflector hood
- Convergent nozzle
- Adjustable stop
- Float Through the rock arm, the float controls the self – centering disc, which regulates the aperture trough the water flows. When the water level in the reservoir rises, the float is lifted thus tending to close the abturator. The

float chamber communicates with the reservoir trough on orifice, which is equipped with a control valve, thus providing and adjustable damping effect.

G.33.20 Strainers

Strainers shall be flange mounted type. Foot strainers shall be installed at least 0.5 m above the bottom of the water reservoirs.

The strainer basket shall be of the perforated cylinder type made from galvanized steel or stainless steel. It shall be easily accessible via a removable flange.

G.33.21 Electromagnetic Flowmeters

The electromagnetic flowmeter consists of a pipe-mounted electromagnetic flow sensor and a signal transmitter either mounted on the sensor or remotely installed and connected via a data cable; to BS EN ISO 6817.

Acceptable manufacturers are ABB, Siemens, Endress&Hauser, Krohne, Euromag, or equivalent Europe/USA made, as approved by the Supervising Engineer.

G.33.21.1 General

The electromagnetic flow sensor shall operate on the electromagnetic induction principle. It shall provide pulse and analogue current output, proportional to volume and rate flow respectively.

It shall be of double-flanged type, robust, fully welded and potted construction with the following specification:

- Material: - Flanges and body: Carbon steel, acrylic coated.
- Inner flow tube: AISI 304, ebonite or equivalent non-conductive, abrasion resistant lining.
 - Suitable for continuous operation,
 - Isolation to IP 68 for immersion up to 1.5 m depth,
 - Suitable for underground installation,
 - Factory calibrated either to ISO 4185 (gravimetric method) or ISO 8316 (volumetric method). Accreditation certificate for the test facility and calibration certificate for the flow meter shall be submitted with the technical offer,
 - Shall have factory sealed power and signal cable. The cable lengths shall be sufficient to permit termination external to the chamber, either at a junction box or at measuring Transmitter, as specified,
 - Shall have earthing electrodes or corrosion resistant earthing rings,
 - Capable of bi-directional reading,
 - Flow measurement shall be largely independent of pressure, density, temperature, viscosity and flow profiler,
 - Shall be bonded by tinned copper braid links at each end to the adjacent pipework to ensure a good connection between the body and the metered liquid,
 - Inlet and outlet straight run: - For DN up to 300 mm inclusive, flow sensor shall be of the type NOT requiring straight runs before and after (U0-D0 installation),
- For DN above 300 mm, required free runs as per manufacturer recommendation unless otherwise stated in the BoQ.

G.33.21.2 Flow Transmitter

The flow transmitter shall be an Electronic Display Unit with comprehensive display.

The signal processing facilities of the converter shall ensure that the output signals are unaffected by interfering voltage, stratified Flow, Changes in fluid electrical conductivity within the limit stated, non-homogeneity of the fluid in the presence of ferrous particles.

The instrument zero shall be factory set premises and thereafter this zero shall be maintained automatically without interruption of flow or output signals.

The zero and output signals shall be unaffected by partly-fouled electrodes.

Measuring Transmitter shall be interchangeable with those of any other electromagnetic flowmeter of the same design.

Calibration checking shall require no auxiliary test meter or simulator. Transmitters shall not be mounted in flow meter chambers subject to Flooding.

Cable distance between the flow sensor and the transmitter as per manufacturer recommendation.

The Following measuring features shall be provides as a minimum additional requirement.

- Pulsed D.C field excitation
- Scaled pulse output for integration counter drive.
- Capabilities of bi-directional measurement with differing forward and reverse ranges and with local and remote indication of reversal.
- Contact operation at a programmable measured value
- Galvanic isolation between each output circuit and between electrode circuit and output circuit.
- Output circuit isolation from earth within the instrument but suitable for earthing.
- Adjustable low flow cut-off
- Self-diagnosis
- Continuously adjustable velocity and flow range settings.
- Terminals accommodated in compartment separate from electronic components
- Empty pipe detection signals Configuration shall be achieved either with a configurator (Lap Top software) or via the integral keypad. It shall be with the software features multi-level password protection to prevent unauthorized configuration changes. In the 2-line display only variant, display data can only be changed, no operational parameters can be changed without the use of a configurator and appropriate passwords.
- It shall be supplied with vendor's software for in situ verification of flow meter calibration
- It shall have an LCD display to indicate instantaneous flow rate/total flow/flow velocity.
- The flow computer shall be microprocessor based and shall have facilities for on-line diagnosis, entering pipe size, engineering units, measuring span etc.
- The flow converter shall provide flow rate and totalized flow indication on its own screen with the ability to transmit the data remotely to a SCADA system.
- The flow converter shall provide 4-20 mA output linearly proportional to the rate of flow.

G.33.21.3 Technical Requirements

A) General The following performance shall be available as a minimum.

True Flow as % of full-scale setting	Maximum Error
50 to 100%	± 0.5% of true value
10 to 50%	± 1% of true value
5 to 10%	± 2% of true value

Repeatability	Not Exceeding $\pm 0.2\%$ of true value
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B) Flow Sensor

- Application : Treated water
- Type : Double-flanged inline electromagnetic
- Size of flow pipe As specified in the BoQ
- Process connection : flanged
- Weather Protection Class IP 68
- Electrodes material: SS 316
- Surge protection devices (SPD) between flow tube and flow transmitter required for protection from lightning surges

C) Flow Transmitter

- Type: Microprocessor based with facility to configure ranges
- Type of display: Build-in and remote transmission to PLC
- Input: From flow sensor
- Output: 4 digital outputs: forward pulse, reverse pulse, alarm 1 and alarm 2 - 2 analogue outputs 4-20 mA DC (isolated) proportional to flow rate

- Communications: RS485 (Modbus communication)

- Power Supply: 240 V AC
- Zero and Span Adjustment: Required
- Weather Protection Class: IP 65
- Facility for on-line diagnosis: Required

G.33.22 Pressure Control or Flow Control Valves

Pressure or flow control valves used for pressure reduction, pressure sustaining or pressure relief or flow control shall be of the double flanged type and shall operate by use of an integral auxiliary pilot circuit suitable for the fluid and shall be actuated by the integral spring and the differential pressure on the diaphragm. For DN less than DN 80 diameter a direct spring controlled valve may be used. Flow control valve shall have a downstream orifice installed and incorporated into the pilot circuit. Valves shall inherently close at backflow. All valves shall have an indicator showing degree of aperture.

Length shall comply with EN 558-1 series 1, flange dimensions and drilling to EN 1092-2 PN 16 (DIN 28605 / DIN 2501).

The valves shall be adequately sized to control the flow and pressure differential required for the application with an accuracy of $\pm 2,5\%$ of the set value. They shall be capable of operating at a sustained pressure 20 % in excess of the nominal declared working pressure.

Globe-type control valves shall have a vertical spring and pressure loaded obturator, a pilot circuit with pilot valve, strainer, stop cocks, throttle needle valve as may be required for the particular purpose. Identical valves except for the elements making up for the pilot circuit shall be used for pressure reducing, pressure sustaining and flow limiting valves.

The main pressure control valve operation shall be actuated by a hydraulic differential pressure system in balance with a spring loaded bellows type diaphragm, the reference pressure being bled from the inlet and outlet of the main valve. The

diaphragm spring shall be adjustable by a screw to cover the range of pressure adjustment specified for the valve application.

Pressure gauges of appropriate range shall be provided upstream and downstream and shall be of class 1,6 100 mm diameter.

G.33.23 Valve Installation

- A. General: Valves, actuating units, stem extensions, and accessories shall be installed in accordance with the manufacturer's written instructions and as indicated. Valves shall be adequately braced to prevent warpage and bending under the intended use. Valves shall be firmly supported to avoid undue stresses on the pipe.
- B. Access: Valves shall be installed with easy access for actuation, removal, and maintenance and to avoid interference between valve actuators and structural members, handrails, or other equipment.
- C. Valve Accessories: Where combinations of valves, sensors, switches, and controls are required, the Contractor shall properly assemble and install such items so that systems are compatible and operating properly. The relationship between interrelated items shall be clearly noted on Shop Drawing submittals.

G.34 Piping

G.34.1 General

The extent of piping systems, to which this specification is to be applied, shall be as indicated on the Contractor's approved shop drawings. However, piping which is furnished as a regular part of proprietary or standardised equipment (or package facility) shall be in accordance with the equipment manufacturer's standards for the design conditions.

Design, fabrication, inspection and testing of piping systems shall be accomplished in accordance with one of the following codes and standards: ASTM, BS, ISO, ANSI or DIN.

Pipe work materials shall normally be selected from the Pipe Material Technical Selection Matrix.

G.34.1.1.1 PIPE MATERIAL TECHNICAL SELECTION MATRIX FOR USE WITHIN WTW and WwTW PLANTS

	MATERIAL										
	Ductile Iron (6)	Steel with Coatings (6)	PE (solid wall)	PE (structured wall)	PVC -A PVC u	ABS (7)	GRP (7)	Concrete (5)	Clayware	Ribbed polyethylene	Perforated Pipework
Gravity - buried free surface flow	X	X		X	X		X	X	X		
Gravity - buried Low pressure	X	X		X(11)	X		X	X(1)			
Gravity - under tanks	X (2)							X(2)			
Gravity - within building low pressure	X	X		X(11)	X	X	X	X			
Rising mains - buried	X	X	X		X		X				
Rising mains - under structure, all pressures	X(2)										
Rising mains - within buildings	X	X(9)	X(3)		X(3)	X(3)					
Surface water drains - non-pressure only				X	X			X	X	X	
Land drains and French drains								X(10)	X	X	X(4) (8)

Key Legend :

X	Normally suitable	5	Sulphate-resisting cement when high sulphates present in ground	10.	Porous concrete	
1.	Prestressed concrete only	6	For contaminated land special emphasis on external protection is required	11.	Max working pressures Pipe - 1 bar Welded joints and Flex Spigot and socket joints Refer to supplier for ma	: seal Couplings 1 bar - 0.5 bar x test pressures
2.	With concrete surround	7	Not UV stable, keep covered	12.	Refer to supplier for pressure irrespective of	max test pressures and CESW1 5, test diameter
3.	Detailed support consideration	8	Fin drains can be used at structures			
4.	Most acceptable materials	9	Includes thin walled stainless steel			

G.34.1.1.2 PIPE MATERIAL TECHNICAL SELECTION MATRIX FOR USE ON WASTE WATER NETWORKS

	MATERIAL										
	Ductile Iron (6)	Steel with Coatings (6)	PE (solid wall)	PE (structured wall)	PVC -A PVC u	ABS (7)	GRP (7)	Concrete (5)	Clayware	Ribbed polyethylene	Perforated Pipework
Gravity - buried	X	X		X	X		X	X	X		
Rising mains - buried	X	X	X		X		X				
Rising mains - within buildings	X	X(10)	X(3)		X(3)	X(3)					
Land drains and French drains								X(11)	X	X	X(4) (8)

Key Legend :

X	Normally suitable	5.	Sulphate-resisting cement when high sulphates present in ground	10.	Porous concrete	
1.	Prestressed concrete only	6.	For contaminated land special emphasis on external protection is required	11.	Max working pressures Pipe - 1 bar Welded joints and Flex Spigot and socket joints Refer to supplier for ma	: seal Couplings 1 bar - 0.5 bar x test pressures
2.	With concrete surround	7.	Not UV stable, keep covered	12.	Refer to supplier for pressure irrespective of	max test pressures and CESW1 5, test diameter
3.	Detailed support consideration	8.	Fin drains can be used at structures			
4.	Most acceptable materials	9.	Includes thin walled stainless steel			

G.34.2 Design

The design pressures and temperatures shall be determined, considering start-up conditions and other requirements for safety as well as normal operating conditions. However, maloperation shall not be taken into account.

Piping shall be routed for the shortest possible run with a minimum number of fittings consistent with provision for expansion and flexibility. The assembly, removal and support of piping and equipment shall also be taken into consideration.

Plastic pipes shall not be used where they would be exposed to direct sunlight.

The minimum horizontal walkway clearance between piping and mechanical equipment shall be 0.80m. The minimum clearances to the bottoms of piping, shall generally be as follows:

- Above platforms/walkways: 2.1m;
- Inside buildings: 2.1m;
- Roads: 5m;
- Mobile lifting equipment access areas: 3.5m;
- At grade (sleepers): 250mm.

To permit ready access, for the removal or maintenance of a pipe line, a minimum side-clearance of 25mm shall be provided between parallel lines, or between flange and pipe. Space for the connection of instrument piping to orifice flanges shall be provided.

The lowest point of all flanges on lines running in trenches, shall be minimum 75mm above the floor of the trench.

All parts of the piping works, including gland packings, etc shall be entirely suitable for use under conditions at the wastewater treatment works.

G.34.3 General Installation Requirements

Rubber bellows type or other expansion joints may be used where necessary. When expansion joints are applied, adequate guides for piping shall be provided to avoid eccentricity of the centre line. Pipe connections to pumps shall be provided with flexible rubber expansion joints.

Dismantling joints shall be incorporated in the pipework to facilitate removal of replaceable maintenance items.

All piping systems shall be designed so that the loads and moments at the flanges of mechanical equipment such as pumps and compressors shall not exceed the permissible reactions for this equipment as specified by the manufacturers of the equipment.

All pipe sections which pass through walls of water retaining structures shall have integral puddle flanges for building in and shall be left uncoated externally over the length encased in concrete.

All piping shall be adequately supported by hangers or supports of proper structural design. Support span shall be determined, considering the stress and strain caused by the weight of the piping component, fluid and insulation. Lines shall be provided with suitable supports to prevent excessive expansion forces on equipment and excessive vibration.

Piping at valves and mechanical equipment, such as pumps, requiring periodical maintenance shall be supported so that the valves and equipment can be removed with a minimum necessity of installing temporary pipe supports.

Pipe support details shall be furnished for piping of DN50 and over, and for piping subject to high pressure and/or vibration. Pipelines DN200 and under shall be supported to carry their weight plus water for hydrostatic test. Pipelines DN250 and over shall be supported to carry their weight under service fluid conditions.

Threaded joints shall be assembled without a seal weld.

Pipework which may be subject to freezing shall be insulated or trace heated and insulated with proprietary insulating materials. The outer surface of the insulation shall be clad with a pre-finished metallic corrosion free sheeting, final colour to client's choice.

Valves shall be installed so that the centre line of the stem shall be not more than 1800mm above the pavement of the platform levels. Frequently operated valves, on which the centre line of the stem is more than 1.80m above the pavement

or platform levels shall be provided with remote operating devices, such as chain wheels, or extension stems to permit ease of operation. Chains shall hang within 0.90m of the operating level. Other valves, which may be used infrequently, and which are not less than 3.60m from the operating level, shall be installed so that they can be reached from an operation stand. Frequently operated valves in trenches shall be provided with extension stems extending to within 100mm below the cover plate when the hand wheels are more than 300mm below the cover plate.

Valves at installations shall be located directly against or close to the installation nozzles unless physical interferences would prevent proper operation of the valves. Valves shall not be located inside vessel or tank skirts.

All valve outlet ends, in process services which do not connect to a piping system, shall be provided with a blind flange or a screwed cap assembly.

Manually operated valves, which are used in conjunction with locally mounted flow indicators, etc., shall be placed at the same operating level and located where the instrument can be readily observed.

Control valves and safety relief valves shall mounted in a location that allows access for maintenance.

Suction lines to pumps shall generally be designed to avoid pockets. The discharge line from centrifugal pumps shall be provided with a check valve between the pump and the isolation valve. For vertical discharge pumps, the check valve shall be located in the vertical line whenever practical. Suction and discharge lines of pumps shall be drained through drains located at the low point of the pump casing whenever possible.

Sealing oil systems and cooling water piping for glands shall be furnished in accordance with the pump manufacturers' recommendation.

On completion of erection, all pipework shall be hydraulically tested to 1.5 times maximum working pressure. The test pressure shall be maintained for 2 hours in the presence of the Engineer and any leaks shall be rectified at the Contractor's expense. The Contractor shall supply all necessary equipment including water, pumps, blank flanges, gauges, etc for these tests.

G.34.4 Ductile Iron Piping

Ductile Iron pipes, fittings and accessories shall comply with ISO 2531 and ISO 4179 External protection shall comprise a zinc layer (ISO 8179) and a top layer of black bituminous paint.

Exposed joints shall be flanged ISO 2531, PN10 (or higher if required by the duty). Gaskets for sewage or sludge services shall be Bunan-N quality. Buried joints shall be of the mechanical or rubber gasket push-on type having a locking device.

G.34.5 Steel Piping

Steel pipes shall comply with, ISO 559 "Steel Tubes for Water and Sewage".

Exposed joints shall be flanged EN 1092-2:2002, PN10 (or higher if required by the duty). Gaskets for sewage or sludge services shall be Bunan-N quality. Buried joints shall be of the slip-on sleeve coupling type with thrust harnesses.

External protection shall comprise a zinc layer and a top layer of black bituminous paint, with an additional PE tape wrapping.

Internal protection shall comprise a cement mortar lining of minimum thickness 6mm for pipes DN100 to DN250 and 8mm for pipes DN300 to DN500.

G.34.6 Stainless Steel Piping

Stainless steel pipes shall comply with, ISO 1127 “Stainless Steel Tubes. Dimensions and Conventional Masses per Unit Length”.

The quality of stainless steel shall be chosen appropriate to the application.

Flanged joints shall be to BS 4504, PN10 (or higher if required by the duty). Gaskets for sewage or sludge services shall be Bunan-N quality.

G.34.7 Glass Reinforced Piping

Glass reinforced pipes shall comply with, “BS 5480 Specification for Glass Reinforced Plastic (GRP) Pipes, Joints and Fittings for Water Supply and Sewerage”, or other accepted ISO or European Standard.

Flanged joints shall be to BS 4504, PN10 (or higher if required by the duty). Gaskets for sewage or sludge services shall be Bunan-N quality.

G.34.8 Thermoplastic Piping

The following plastic piping materials conforming to ISO, ASTM or BS may be used:

Polyvinyl Chloride (PVC);

Acrylonitrile-Butadiene-Styrene ABS;

Polypropylene (PP);

Polyethylene (PE);

Fibreglass Reinforced Plastic (FRP)

Plastic pipes shall not be used for services where they will be exposed to direct sunlight. FRP pipes shall not be used for buried services.

Joints on PVC piping may be solvent welded, flanged or push-on type with rubber gaskets. Gaskets for PVC flanges shall be 3mm thick ethylene propylene rubber (EPR), full faced, and with a Durometer hardness of 50 to 70 Shore A. When connecting PVC flanges to raised face metal flanges the raised face shall be removed.

Supports, anchors, fixing points, pipe laying and pipe handling shall all conform to the methods, materials and equipment recommended by the piping manufacturer.

G.35 Compressed Air Systems

G.35.1 General

The compressed air distribution system shall commence at the packaged air compressor/receiver unit.

The maximum working pressure of the installation shall be determined by the Contractor to suit his design requirements.

G.35.2 Workmanship

The compressed air distribution system shall be installed in a professional and workmanlike manner in accordance with the Code of Practice "Selection and Installation of Compressed Air Services", published by the British Compressed Air Society or similar European document.

All pipework shall present a neat appearance and surplus jointing material shall be removed from around fittings. Brackets and hangers suitable for the purpose shall be firmly secured to the steelwork within the buildings to adequately support and restrain the pipework system and accessories. Adequate allowance shall be made to accommodate thermal expansion and contraction within the system.

G.35.3 Materials

All materials used shall be suitable for the purpose intended and shall be free from blemish, corrosion or irregularity. Jointing materials used in conjunction with the distribution system shall be suitable for use with compressed air.

The following materials shall be used:

- Pipework - Galvanised mild steel heavy grade tube with screwed ends;
- Fittings - Galvanised mild steel malleable iron fittings with screwed ends;
- Stop Valves Erhard ball or equal and approved;
- Water Traps - Rexroth or equal and approved;
- Air Filters - Rexroth or equal and proved;
- Air Pressure Regulator - Rexroth with adjustable knob or/and equal approved;
- Air Lubricator - Rexroth or equal and approved, complete with oil charge suitable for the compressed air tools to be employed;
- Compressed Air Connections - 'Quick - Fit' type as manufactured by Rexroth or equal and approved.

G.35.4 Commissioning and Testing

The compressed air distribution system shall be pressure tested to one and a half times its maximum working pressure and this pressure shall be maintained without significant loss for 30 minutes. Care shall be taken to ensure that all pressure vessels and equipment likely to be damaged by the application of the pressure test are isolated.

The compressed air distribution system shall be commissioned and adjusted to obtain the pressures and flow rates required at the various outlets. Checks shall also be carried out to ensure that any condensation forming within the system is adequately drained away.

G.36 Lobe Type Air Blowers

Provide labour, materials, equipment and services, and perform operations required for complete installation of lobe type air blowers and related work as specified herein and shown on the Contractor's approved shop drawings.

Materials and work shall conform to the latest edition of reference specifications, industry standards listed below and specified herein and to applicable codes and requirements of local authorities having jurisdiction, whichever is more stringent.

Exercise proper care in the handling of work so as not to injure the finished surfaces, and take proper precautions to protect the work from damage after it is in place.

Blowers shall be positive displacement type, designed to give a completely free oil free discharge. Blowers and motor units shall be designed for an operating life of 20 years without major overhauls.

Furthermore, blowers shall not need normal maintenance procedures requiring replacement of parts within the first 18 000 hours of operation, except for lubricants and filters.

Components likely to become worn in the course of normal operation shall be capable of replacement, making use of readily exchangeable components.

The blowers shall have high quality cast iron casing with integral feet. The shafts and two or three lobe rotors shall be integral construction from spheroidal graphite iron with seals of suitable material. These shall fully machined and phase maintained through the use of pressure lubricated timing gears which shall be hardened and profile ground.

Bearings shall be of a single roller grease lubricated type at the driven end, and double row deep groove ball type oil lubricated at the gear end. Labyrinth seals and nitrile "O" ring seals shall be fitted inboard the bearings to prevent air leakage and contamination.

Each blower shall be provided with a coupling or belts, guard and electric motor, and the whole assembly shall be mounted on a base-plate with vibration isolators.

For direct coupled units, the blower and motor shall be dowelled in position, following satisfactory commissioning, to ensure correct re-alignment following dismantling.

The base frame shall include facilities for lifting the combined blower/motor/base frame assembly.

Each blower shall be provided with:

- a) Suction filter and noise attenuator with a capture efficiency of 98% at 5µm b) Air filter blocked indicator including an electronic remote signal c) Discharge noise attenuator d) Pressure relief valve and electrical overpressure shut-off e) Non-return valve and isolating valve f) The pipeworks connections shall be flexible to avoid transfer of vibrations. The Manufacturer shall offer blowers from within a standard range to meet the requirements of the complete system and provide the range of flows required. They shall be sized for the variations in atmospheric pressure, temperature and relative humidity stated below:

Standard Conditions:

- Air Temperature: 15°C
- Relative Humidity: 75%
- Atmospheric Pressure: 1013 mbA

Standard Operating Range: Minimum Maximum

- Air Temperature 5°C 35°C
- Relative Humidity 25% 100%
- Atmospheric Pressure 950 mbar 1050 mbar

The blowers shall be sized to give maximum operating efficiency at the standard conditions. The blowers shall be capable of operating over the stated operating range.

Blower efficiencies are to be quoted for the minimum and maximum operating conditions.

If the blower cannot obtain the specified noise level, it shall be equipped with the necessary noise reducing enclosure made of galvanized steel sheets with insulation material so that the noise emitted at a distance of 1.0m should not exceed 80 dB.

The enclosure shall be easily demountable with snap locks.

Where forced ventilation is necessary in conjunction with acoustic enclosures and oil cooling, the rating of the fan motors used for this purpose shall be included in the Manufacturer.

The additional loading represented by forced ventilation fans will be taken into account when calculating the overall system operating efficiency.

G.37 Pumps

The Contractor shall provide pumps and pumping appurtenances, complete and operable, in accordance with the Contract Documents.

The provisions of this Section shall apply to pumps and pumping equipment throughout the Contract Documents except where otherwise indicated.

Unit Responsibility: The Contractor shall be responsible to the Engineer for furnishing the WORK assembly, testing, and installation of the WORK of each pump Section and for compliance with the requirements of each pump Section.

Manufacturer: Where two or more pump systems of the same type or size are required, the pumps shall all be produced by the same manufacturer.

The Raw water intake pumps, the High service pumps, the intermediate pumps and the raw water intake de-silting pumps shall be identical in all respects to the existing pumps.

G.37.1 Contractor Submittals

- A. Furnish submittals in accordance with Mechanical Requirements.
- B. Shop Drawings: Shop Drawings shall contain the following information:
 - 1. Pump name, identification number, and specification Section number.
 - 2. Performance data curves showing head, capacity, power demand, NPSH required, and pump efficiency over the entire operating range of the pump. The equipment manufacturer shall indicate separately the head, capacity, power demand, overall efficiency, and minimum submergence required at the design flow conditions and the maximum and minimum flow conditions. The curves will be executed for all the required duty points.
 - 3. The Contractor shall require the manufacturer to indicate the limits on the performance curves recommended for stable operation without surge, cavitations, or excessive vibration. The stable operating range shall be as wide as possible based on actual hydraulic and mechanical tests.
 - 4. Assembly and installation drawings including shaft size, seal, coupling, bearings, anchor bolt plan, part nomenclature, material list, outline dimensions, and shipping weights.
 - 5. Motor Data proposed for each pump, in accordance with Section Electrical Works.
 - 6. Proposed control panel showing panel-mounted devices, details of enclosure type, single line diagram of power distribution, and current draw of panel, and list of all terminals required to receive inputs or to transmit outputs from the local control panel.
 - 7. Wiring diagram of field connections with identification of terminations between local control panels, junction terminal boxes, and equipment items.
 - 8. Complete electrical schematic diagram.
- C. Technical Manual: The Technical Manual shall contain the required information for each pump Section.
- D. Spare Parts List: A spare parts list shall contain the required information for each pump Section.
- E. Factory Test Data: Signed, dated, and certified factory test data for each pump system which requires factory testing, submitted before shipment of equipment.
- F. Certifications

1. Manufacturer's certification of proper installation.
2. Contractor certification of satisfactory field testing.

G.37.2 References

A. Reference Standards

The following codes and standards are intended to provide an acceptable level of quality for materials and products.

1. ISO 9906: 2012, HI 11.6/14.6 Gr 2B
2. Hydraulic Institute (HI): - HI E.35.01 Centrifugal Pumps.
3. American National Standards Institute (ANSI):
 - ANSI B15.1 Safety standards for mechanical power transmission apparatus.
4. American Society for Testing and Materials (ASTM):
 - ASTM A36 Structural Steel.
 - ASTM A48 Gray Iron Castings
 - ASTM A53 Pipe, Steel, Black and Hot Dipped Zinc-Coated, Welded or Seamless.
 - ASTM A278 Gray Castings for Pressure Containing Parts for Temperatures up to 650 ° F (345 ° C).
 - ASTM A296 Corrosion -Resistant, Iron-Chromium, Iron-Chromium- Nickel, and Nickel-Base Alloy Castings for General Application.
 - ASTM A536 Ductile Iron Castings.
5. American Water Works Association (AWWA):
 - AWWA E101 Vertical Tubing Pumps - Line shaft and submersible.
6. American Petroleum Institute (API): - API 610
7. National Electric Code (NEC)
8. National Electrical Manufacturer's Association. (NEMA)
9. American Bearing Manufacturers Association (ABMA)

G.37.3 Products

G.37.3.1 General

- A. Compliance with the requirements of the individual pump Sections may necessitate modifications to the manufacturer's standard equipment.
- B. Performance Curves: Centrifugal pumps shall have a continuously rising curve or the system operating range shall not cross the pump curve at two different capacities or "dip region." Unless indicated otherwise, the required shaft horsepower for the entire pump assembly at any point on the performance curve shall not exceed the rated horsepower of the motor or engine or encroach on the service factor.
- C. Components of each pump system provided under the pump Specifications shall be entirely compatible. Each unit of pumping equipment shall incorporate basic mechanisms, couplings, electric motors, necessary mountings, and appurtenances.
- D. All pump units shall have means of isolation from their associated pipe work system.
- E. In dry well installations, the suction valve will normally be left open, unless used for isolation when the pump is out of service. Materials shall be suitable for the intended application; materials not indicated shall be high-grade, standard commercial quality, free from defects and imperfections that might affect the serviceability of the product for the purpose for which it is intended.

Pump Duty shall be of the type specified. They shall be designed to give specified output against all losses including those relating to the pump.

The Contractor shall match his pump characteristics to the pipe system network to achieve high pump efficiency and reliability.

Each set must be capable of running satisfactorily in parallel with other sets in the system without throttling and by itself, without cavitation or overload under all operating conditions within the system characteristics given.

The pump section and arrangement shall be such as to ensure that the head available exceeds the N.P.S.H. requirements of the pump under all operational conditions.

Where the system and pump characteristics are such as to give rise to the possibility of surge in the pipeline with consequential damage, a surge investigation shall be undertaken; if the results of the investigation show that there is a problem, measures shall be proposed by the contractor to alleviate the problem. These measures shall be agreed with the Engineer.

Centrifugal pumps shall have a non-overloading characteristic over the complete range of head and quantity delivered and the drive shall be capable of starting the pumps against a closed valve, i.e. maximum pump head conditions.

The whole pumping unit shall be capable of withstanding without detriment, reverse rotation to a speed that would occur if the pump were to stop when the differential head was at a maximum and the delivery and/or non-return valve failed to close.

The design of the pumps shall be such that there will be no tendency to unlock any part due to possible reversal of rotation and shall not pass through or approach a critical speed.

The pumps shall be capable of working for long periods without cleaning or attention.

Pump Duty Control : Each of the pump units shall be capable of operating in any combination of duty sequence. Any starting sequence, including those following restoration after a supply failure shall be time sequenced to prevent excessive load on the supply system. Each duty circuit shall include its own timer, arranged to be initiated in the selected duty sequence by the preceding duty, the delay periods between each re-start being adjustable up to 20 secs. Pumping sets shall be automatically operated according to water levels in the discharge and suction side reservoirs unless otherwise specified.

Successive levels shall be carefully chosen in order to ensure a smooth and safe operation of the pumping system, taking into consideration the characteristics of the pumps, networks, hydraulic inertia of the installation, as well as the sensitivity of the instrumentation.

Two sets of level measuring devices operating in redundancy shall be installed in each reservoir unless otherwise specified.

Where valves with motorized actuator are installed on pump outlet pipe section, or at the rising main, the pump shall be started with a closed valve: each pump shall start when the valve is still closed. The valve begins to open at the starting command of the pump and shall be controlled by the discharge pressure. The time of the total opening of the valve shall be chosen according to the pump manufacturer recommendation. At the pump stop command, the corresponding valve shall receive a closing signal and shall close fully prior to the shutdown of the pump. Where more than one pump set is installed for a water network and unless otherwise specified, pumps shall be operated with a cyclic duty program automatically executed by the supervisor system. However, a selection of pump duty order by the operator shall be possible.

Pump Casings shall be capable of withstanding all pressures which may be produced due to operating pressure surges.

Particular attention shall be paid to the wear characteristics of the pumps.

The pump design shall ensure that alignment is maintained between the various assemblies by recesses, spigots and dowels and shall be such that all components liable to wear can be replaced.

Components shall be permanently marked with the manufacturer's number and where dowels are not used, permanently marked for correct assembly.

The casings of the pumps shall have flanges to match the specified pipe work.

The waterways through the pumps shall be smooth in finish and free from recesses and obstructions.

All pumps shall incorporate bearing arrangements which prevent the escape of lubricant into the liquid being pumped. The bearings shall be located in dust/moisture-proof housings.

All bearings shall be liberally rated to ensure cool running and meet the load factors specified.

For vertically mounted pumps, the top bearing shall be a combined thrust and journal type, designed to prevent any thrust loads being transmitted to the drive motor. The pump bottom bearing shall be lubricated by an enclosed water lubricated sleeve bearing for potable water applications but by grease or other approved means for sewage use. Storm pump bearings shall also be suitable for standing idle for periods up to 2 months without attention or movement.

Where grease points are necessary they shall be fitted with removable screwed plugs which shall be accessible without removing guards. All bearings having automatic lubrication shall also have provision for hand lubrication.

A lubrication system shall be arranged for the lubrication of all grease points on the pumps and shafting from motor room level. Individual bearings within the support tunnel tubes and on the pump sets themselves shall receive separate supplies of grease fed by pressure tubes laid from each bearing to battery plates readily accessible from motor floor level for grease gun operation.

Pressure tubes shall be grouped together where possible and securely attached by brackets, straps etc. to tunnel tubes, with connectors located near to the motor support plate for easy removal of shafting in the event of maintenance work. In exposed positions pressure tubes are protected from damage. Motor grease points will not be included in this lubrication system but shall receive individual attention.

The battery plates shall have sufficient greasing points for all bearings and be located on or adjacent to each pump motor stool.

A notice is to be supplied and fixed on the wall in a prominent position detailing the manufacturer's recommended greasing schedule. The notice shall include a warning of the dangers to bearings from 'over greasing'.

A grease gun shall be supplied for all greasing purposes.

Bearings which require a continuous supply of lubricant shall incorporate a means of monitoring such a supply, either by flow or temperature rise as appropriate for the type of bearing employed; separate monitors being fitted for each bearing feed or housing.

Such monitors shall include all necessary ancillary power or pulse counting devices to enable the operation of any monitor to initiate a volt free contact rated at 240V 0.5A AC.

Where specified, each pump shall be equipped with cast aluminum or fabricated steel tundish to accommodate the drain lines from mechanical seals, casing vent and other minor drainage points on the pump. A single drain pipe shall be run from the tundish to the house drainage system.

The highest point on the pump casing shall be fitted with a manual air release cock having a removable handle or an automatic air release valve with a lockable isolation valve as specified. The drain from each air release cock shall discharge via pipe work as specified.

Coupling materials shall be chromium stainless steel.

All couplings shall be of an approved type and the Contractor shall arrange for the provision and fitting of both coupling halves to each respective shaft and shall include for all necessary modifications to any existing shafts to be coupled.

Where specified, the Contractor shall include any equipment required to prevent damage to any part of the drive in the event of reverse rotation of the pumps.

Intermediate shafts between the pump and drive shall include universal couplings at each end allowing free axial movement to avoid end thrust being transmitted. The shaft and coupling shall be fitted with a full length guard manufactured from mild steel mesh on a mild steel framework, easily removable for maintenance purposes.

Each unit shall be continuously rated to transmit the full power of the drive either directly in line or through a right angled, helical gear system, having an input/output speed ratio to suit the duty.

The gear case shall be made of substantially ribbed cast iron with machined mounting feet and shall form a totally enclosed, oil tight casing.

The gear unit case and bearings shall be designed to accommodate the total weight of any suspended drive shafting and couplings in addition to any dynamic load imparted during service, and run for a minimum of 10,000 hours before a major overhaul is required.

Where specified, an electric tachometer shall be fitted to indicate the output shaft speed.

Lubrication: The gear unit shall be grease or oil lubricated, arranged to provide an adequate supply of lubricant for the duty.

Where oil lubrication is employed, the casing shall include an oil breather, level indicator and drain plug.

Units having a rated output greater than 500kW shall have inspection covers and include a forced lubrication system comprising oil circulating pump, reservoir tank and full flow

'Duplex' type oil filters having re-usable elements together with associated pipe work; the oil being circulated by either (a) an internal mechanically driven gear pump and an external electrically driven pump arranged to prime the gears as pre-set timings as recommended by the unit manufacturer, or (b) duplicate external electrically driven pumps, each of which may be selected to prime at pre-set intervals and run when the gear unit runs.

Such a lubrication system shall include dial gauges and alarm switches to monitor high oil temperature and low oil pressure.

Reverse rotation: Where specified, the gear unit shall be capable of withstanding reverse rotation for a limited period with no detriment to the unit. Where a forced lubrication system is used, this shall continue to operate satisfactorily under such conditions.

G.37.4 Factory Testing

The following tests shall be conducted on each pump:

1. Motors: Electric motors shall be tested. Test results shall be furnished to the pump manufacturer prior to the pump test.
2. Factory Tests: a. All hydrostatic and performance testing shall be completed prior to the

application of any paint and/or coating. All factory testing shall be in accordance with the standards of the Hydraulic Institute. All testing is to be performed at the pump manufacturer's facility.

- b. Hydrostatic testing shall be held at a pressure of 1-1/2 times the pump shutoff head for a period of not less than five (5) minutes. A hydro certificate shall be completed after the test and included in the final data package.
 - c. Performance testing shall be performed on the fully assembled unit at the rated speed. The test shall be run for a minimum of 30 minutes covering five (5) points including the rated point. A single line certified performance curve shall be completed after the test and included in the final data package.
 - d. Field/functional testing shall be performed to insure proper mechanical operation at the jobsite. All testing data to be used for evaluation shall be performed at the pump manufacturer's facility.
3. Acceptance: In the event of failure of any pump to meet any of the requirements, the Contractor shall make necessary modifications, repairs, or replacements to conform to the requirements of the Contract Documents, and the pump shall be re-tested until found satisfactory.

G.37.5 Execution

G.37.5.1 Services of Manufacturer

- A. Inspection, Startup, and Field Adjustment: Where required by the individual pump Sections, an authorized service representative of the manufacturer shall be at the Site continuously to supervise the following and to certify in writing that the equipment and controls have been properly installed, aligned, lubricated, adjusted, and readied for operation.
 - 1. Installation of the equipment
 - 2. Inspection, checking, and adjusting the equipment
 - 3. Start-up and field testing for proper operation
 - 4. Performing field adjustments to ensure that the equipment installation and operation comply with requirements.
- B. Instruction of the OWNER'S Personnel
 - 1. Where required by the individual pump Sections, an authorized training representative of the manufacturer shall visit the Site for the number of days indicated in those Sections to instruct the OWNER'S personnel in the operation and maintenance of the equipment, including step-by-step troubleshooting with necessary test equipment. Instruction shall be specific to the models of equipment provided.
 - 2. The representative shall have at least 2 years experience in training. A resume for the representative shall be submitted.
 - 3. Training shall be scheduled a minimum of 3 weeks.
 - 4. Proposed training material and a detailed outline of each lesson shall be submitted for review. Comments shall be incorporated into the material.
 - 5. The training materials shall remain with the trainees.
 - 6. The OWNER may videotape the training for later use with the OWNER'S personnel.

G.37.5.2 Installation

- A. General: Pumping equipment shall be installed in accordance with the manufacturer's written recommendations.
- B. Alignment: Equipment shall be field tested to verify proper alignment and freedom from binding, scraping, shaft run-out, or other defects. Pump drive shafts shall be measured just prior to assembly to ensure correct alignment without forcing. Equipment shall be secure in position and neat in appearance.
- C. Lubricants: The CONTRACTOR shall provide the necessary oil and grease for initial operation.

G.37.5.3 Field Tests

- A. Each pump system shall be field tested after installation to demonstrate: 1. Satisfactory operation without excessive noise and vibration. 2. No material loss caused by cavitations. 3. No overheating of bearings. 4. Indicated head, flow, and efficiency at design point. B. The following field testing shall be conducted: 1. Start-up, checks, and operates the pump system over its entire speed range. The pump and motor shall be tested at the RPM indicated for each. Unless otherwise indicated, vibration shall be within the amplitude limits recommended by the standards at a minimum of 4 pumping conditions defined by the ENGINEER. 2. Obtain concurrent readings of motor voltage, amperage, pump suction head, and pump discharge head for at least 4 pumping conditions at the indicated RPM. Check each power lead to the motor for proper current balance. 3. Determine bearing temperatures by contact type thermometer. A run time until bearing temperatures have stabilized shall precede this test, unless insufficient liquid volume is available. 4. Electrical and instrumentation tests shall conform to the requirements of the Electrical section. C. Field testing will be witnessed by the ENGINEER. The CONTRACTOR shall furnish 3 Days advance notice of field testing. D. In the event any pumping system fails to meet the indicated requirements, the pump shall be modified or replaced and re-tested as above until it satisfies the requirements. E. After each pumping system has satisfied the requirements, the CONTRACTOR shall certify in writing that it has been satisfactorily tested and that final adjustments have been made. Certification shall include the date of the field tests, a listing of persons present during the tests, and the test data. F. The CONTRACTOR shall be responsible for costs of field tests, including related services of the manufacturer's representative, except for power and water, which the OWNER will bear.

G.37.6 Double Disc Pumps

The double disc pump shall comprise two reciprocating, mechanically driven, tough resilient discs with a sufficiently large cavity between the discs to produce displacement in a smooth continuous flow.

The pump shall be valveless and glandless and be capable of operating dry indefinitely without pump damage occurring.

The double disc pump shall be available as a static or mobile unit, as specified. It shall be suitable for either electric motor or diesel engine drive, as specified.

The pump body shall be manufactured from cast iron to BS 1452 Grade 220, as a minimum. The discs shall be manufactured from Nitrile rubber or equivalent.

G.37.7 Diaphragm Pumps

The pump shall be of the diaphragm type utilizing a bullfrog type valve, suitable for pumping viscous solutions containing solids up to 55mm diameter as specified. It shall be driven by an electric motor through an oil bath reduction gear unit.

The main body of the pump shall be manufactured from LM6 aluminum and all wetted parts shall be supplied in 316 stainless steel.

The diaphragm shall be manufactured from neoprene, nitrile, hyperlon or viton elastomers and shall be reinforced with polyester fabric.

G.37.8 Submersible Borehole Pumps

G.37.8.1 General

Pumps impellers shall be closed or semi open type made from zinc free bronze or such other material required for use with the particular water to be pumped.

Pump body shall be treated against corrosion. The bowls shall be joined by flanges or by tie rods.

The shaft main guide bearings located in the suction and delivery end housings of the pump shall utilize a leaded-bronze material, and shall be provided with protection guards to prevent ingress of sand and grit. Pump bowl guide bearings shall utilize either leaded bronze or other approved abrasion resistant material.

All pump bearings shall be lubricated by the water to be pumped. The pump delivery end housing shall incorporate a thrust washer of suitable material at the shaft end to absorb upthrusts that occur during pump starting. Unless otherwise specified, the pump shall incorporate a delivery check valve of hydrodynamic shape fitted with a spring to prevent reverse rotation of the shaft from back flow of water through the pump.

The pumps shall be provided with a flanged discharge connection suitable for operating against the pump closed valve head or 16 bar whichever is the greater. The shaft coupling connecting the pump and driving motor shall be accurately machined and keyed to ensure precise shaft engagement and alignment. A strainer of suitable corrosion and abrasion resistant material, designed to guard against entry of foreign matter but permitting unrestricted flow of water into the pump, shall be provided on the pump suction housing.

Protection against the effect of sand shall be provided by renewable wear rings (made from a hard smooth flexible material such as polymethane) mounted at the seating of the impellers and the passages of the shaft.

The pump shall be designed to pump water having a sand content of up to 40g/m³, unless otherwise specified.

A centralizer shall be fitted to every pump to ensure central alignment of the pump set in the borehole casing.

Efficiency shall be greater than 70% at the operating point.

G.37.8.2 Borehole Pumps Rising Column

Borehole rising column shall be seamless steel and provided in section lengths not exceeding 3 meters with flanged joints or screwed couplings according to API5L grade B or equivalent. The rising column shall allow for small deviations in borehole verticality. Cables and water level dip tubing shall be securely fixed to the rising column by straps or bands at approximately 2 meter intervals.

The rising column shall be sufficient to take the stresses generated by the hanging weight of the pump, motor and rising column, the stresses produced by the water pressure together with any dynamic stresses which may occur under any circumstances including valve closure.

The rising column shall be protected internally and externally in factory against corrosion by a non toxic epoxy resin coating (300 Pm minimum thickness) suitable for use with potable water.

G.37.8.3 Borehole Pumps Head Works

A fabricated steel discharge head piece shall be provided at the top of the borehole to support the complete rising column and electro-submersible pump set assembly, and shall be complete with lifting eye bolts. The discharge head piece shall comprise a heavy duty sealing plate arranged for bolting to the borehole outer casing flange, and a 90° discharge bend arranged for flanged connection to both rising column and horizontal surface pipe work. Lifting eyes shall be provided in the sealing plate. A flange shall be provided and welded by the Contractor to the top of the borehole

outer casing. The flange shall be suitably drilled to accommodate the discharge head piece sealing plate bolts. Holes shall be provided in the sealing plate to accommodate an air vent pipe, motor and control cables, water level dip tubing, etc. and shall include adequate sealing arrangements to protect against borehole contamination.

A 25mm diameter screwed removable plug shall be provided over the dip tubing for water level measurement with electrical contact tape. A stainless steel air vent pipe shall be fitted to the discharge head sealing plate, terminating in an insect proof screen and arranged to prevent entry of rain or surface water.

G.37.9 Vertical Turbine Pump Sets

The pumps shall be of the vertical line shaft type. The discharge head shall be bolted onto a substantial steel bedplate or frame which shall in turn be bolted to the pump room floor. The discharge head shall have a flanged discharge. Replaceable seal rings shall be fitted on the impeller suction side if required to maintain pump hydraulic efficiency.

The pump shaft shall be of chromium stainless steel (13% chromium) minimum supported by bearings above and below each stage. Protection shall be given against the effects of entrained solids in the water being pumped intermediate bearings shall be lubricated by the liquid being pumped.

The line shaft shall be of the same material as the pump shaft, supplied in lengths not exceeding 3.0m, and with screwed couplings. The line shaft bearings shall be spider type to locate the shaft in the tube and may also double up as line shaft tube couplers. Lubrication shall be provided to the bearings.

The pump suction shall be of at least equal diameter to the pump and shall be fitted with a suction strainer.

Means shall be provided of adjusting the pump shaft tension and position.

G.37.10 Sump Drainage Pump Sets

Sump drainage pumps shall be vertical spindle submersible motor driven close-coupled units comprising a single stainless steel shaft, a squirrel cage electric motor and an end suction pump.

Electric motors shall comply with IEC 34 & IEC 72. Motors shall have IP68 protection and be SI continuously rated for use both when submerged at ambient temperature and when in air. Motor windings shall be fitted with normally closed thermostats complying with IEC 34-11. Motor feed cables shall be ethylene propylene rubber insulated flexible cable with each power core of tinned copper wire, insulated and polychloroprene sheathed overall.

G.37.11 Packaged Booster Sets for Cold Water Supply

G.37.11.1 General

The set shall be a self-contained, fully automatic packaged unit which requires the minimum of maintenance to give maximum trouble-free operation. The systems consist of either 2, 3 or more individual pump and motor units which operate independently of one another and react immediately to fulfil system demand.

Each set incorporates diaphragm pressure vessels ready with a supply of water when demand arises. When draw-off exceeds the vessel's storage capacity, the lead pump is automatically started by a pressure switch to cope with the demand. In the event of unusually high demand, or failure of the lead pump, the support pump (or pumps) will immediately start.

G.37.11.2 Pumps

Pumps shall be Vertical multistage or horizontal end-suction centrifugal with closed coupled type, stainless steel casing and bronze impeller, complete with electric motor.

G.37.11.3 Control Panel

Sheet steel enclosure incorporating all electrical components necessary for an automatic operation of the pump set. Interwire with motors and pressure switches, requiring only connections to main supply on site. In the event of malfunction of any pump a stand-by pump will start automatically and panel will visually identify the faulty unit. The control panel incorporates a manual selector switch to allocate the role of lead pump in turns, to ensure an even distribution of work load. The control panel should be dust proof and splash proof.

G.37.11.4 Motors

Totally enclosed fan cooled (TEFC) direct-coupled motors, for 50 Hz supply, 380 voltages class F insulation.

G.37.11.5 Pressure Vessel

Mild steel construction incorporating replaceable non-toxic butyl rubber diaphragm. Factory pre-charged to required pressure, eliminating the need for a compressor on site.

G.37.11.6 Valves

Each individual pump has an inlet and outlet isolating valve and a non-return valve on the discharge of each pump. This allows any pump to be removed from the set without the necessity to shutdown the system. An isolating valve is fitted on the pressure vessel line.

G.37.11.7 Pressure Manifold

Each pump is controlled by its own individual pressure switch, factory set for system requirements and mounted with a common discharge pressure gauge on an aluminum manifold block. Receiving their signal through a high pressure PVC pipe which is connected to the discharge pipework.

G.37.11.8 Pipework

Pipe work supplied in galvanized steel or polypropylene or as directed by the Engineer.

G.37.11.9 Base Frame

To be fabricated from 6 mm, flat mild steel plate, complete with panel support and holding- down lugs drilled and tapped to secure all pump set components.

G.37.12 Double Suction Pumps

G.37.12.1 General Description

- A. Scope: Contractor shall furnish and install all labor, materials, equipment, appurtenances, specialty items, and services required for complete and operable Double Suction Pumps as shown and specified in the Contract Documents.
- B. Equipment Coordination: To ensure that all the equipment are properly coordinated and will function in accordance with the requirements of the Contract Documents, the Contractor shall retain ultimate responsibility under this Contract for equipment coordination, installation, operation and guarantee.

Single stage, double suction, axial split casing pumps shall be designed to meet the needs of raw, clean, sea and brackish water applications.

They shall be focused on municipal water treatment, supply and distribution where typically a higher level of standardization is required, allowing the most cost effective solutions and shortest lead times.

G.37.12.2 Construction

G.37.12.2.1 Casing

The casing shall be of axially split design, with integral suction and discharge nozzles on the lower part.

Flanges are of raised face type and drilled according to DIN EN1092-2 PN25.

It shall be of double volute type to optimize the radial load balance and minimize the shaft deflection, with swirl free design for low energy loss at suction and optimum NPSHR.

The casing shall have a compact design to reduce the bearing span and increase the shaft stiffness.

The cutwater shall be designed to minimize radial load pulses and with ample distance from the impeller outer diameter, to reduce vibrations.

The pump shall be designed for easy maintenance, with Dowel pins for alignment of casing halves and precision register fits that don't required adjustment of the rotor assembly in the casing.

Renewable casing wear rings protect the casing from wear. Wear ring is locked against rotation in the lower half casing.

Casing shall be made of ductile iron ASTM A395 Gr 60-40-18 (DIN EN-GJS-400-18).

G.37.12.2.2 Impeller

The impeller shall be of double suction type, keyed and axially secured.

It shall be have non staggered vanes without middle rib and it shall be optimized for high efficiency over a wide range of flows and for low NPSHR also at run-out.

Impeller shall be made of stainless steel ASTM A743 CF3M (DIN EN 1.4409+AT).

G.37.12.2.3 Shaft

The shaft shall be of full dry design (never in contact with pumped medium) to prevent rusting.

Shaft shall be made of chrome-molybdenum steel ASTM A434 Gr 4140 Cl. BC (DIN EN 1.7225+QT)

Shaft sleeve shall be made of stainless steel ASTM A276 Type 316L A (DIN EN 1.4404+AT)

G.37.12.2.4 Shaft Sealing

The shaft sealing shall be made with gland packing with lantern ring (mechanical seal as option).

Plan 11 with stainless steel piping shall be adopted for seal flushing.

Shaft sealing shall be made of ductile iron ASTM A395 Gr 60-40-18 (DIN EN-GJS-400-18)

G.37.12.2.5 Bearings

The bearing housing shall have a 360° fixation for enhanced stiffness and it shall be finned for optimum heat dissipation.

Provisions for temperature and vibration monitoring shall be provided.

Sealing shall be with maintenance free brass bearing isolator (labyrinth).

For vertical arrangement, the following bearings shall be used:

- Thrust bearing at DE: grease lubricated angular contact bearing series 7300
- Product lubricated bearing at NDE: bearing bushing in Vesconite Hilube, provided with flushing.

Bearings, bearing nuts, bearing isolators, mechanical seal, shaft seal sleeves are replaceable without removing the upper casing.

G.37.12.2.6 Coupling

It shall be of non-lubricated dry flexible coupling with spacer.

G.37.12.2.7 Motor cable

Pump motor cable shall be suitable for non-submersible pump applications.

G.37.12.2.8 Control Panel

Each pump shall be provided with a control panel for the automatic operation of the pumps.

G.37.12.2.9 Execution

Comply with manufacturer's product data, including technical bulletins, product catalogue installation instructions.

G.37.12.3 Examination

Examine the pits to receive the pumps. Notify the Engineer of conditions that would adversely affect installation or subsequent utilization and maintenance of the pumps. Do not proceed with installation until unsatisfactory conditions are corrected

G.37.12.4 Installation

- A. Install pumps as indicated on the Installation, Operation and Maintenance Manual (IOM) and contract drawings
- B. Install pumps in accordance with manufacturer's instructions

G.37.12.5 Protection

- A. Protect installed pumps from damage during installation.
- B. All VFDs and soft starters shall be furnished under Electrical specifications, and shall be of the same manufacturer and furnished by a single supplier. The Contractor shall have unit responsibility for proper coordination to ensure all VFDs and soft starters furnished and installed on the entire project are of the same manufacturer. The Contractor shall have sole and complete responsibility for the satisfactory installation and operation of the entire pump station system including pumps, motors, VFDs, soft starters, and controls as specified by the Contract Documents. The pump manufacturer shall assume unit responsibility for the pumps and motors, and shall assume responsibility that the motors supplied with the pumps will successfully start, accelerate and operate the variable speed pumps over the specified operating speed range, and that the pump package including motors and solid state reduced voltage starters and VFD drives will operate successfully over the speed range and meet all other operating characteristics specified in the Contract Documents, including the specified number of starts per hour.

G.37.13 Horizontal Multistage Centrifugal Pumps

The Vendor shall furnish horizontal, multistage-centrifugal pumps and all appurtenances as specified. The pump shall be of heavy-duty construction intended for services of drinking water, gentle pumping action, high efficiency, and low NSPHR.

G.37.13.1 Details of Construction

- A. Construction: Multistage centrifugal pumps with radial cross-section for horizontal or vertical installation. Radial inlets and outlets rotating 90 degrees, with standard UNI/DIN flanges. Closed radial impellers and intake impeller in first stage for improved NPSH. Stages are coupled to each by O-ring seals and secured by strong bolts.
- B. Support-axial thrust: The pumps are provided with double supports with oversized bearings and a hydraulic pressure-balancing device. Flanged support with grease or oil-bath lubrication on both sides of the pump . Radial clamping , on the controls side , is provided by roller bearings. Axial clamping , on the side opposite the controls, is provided by oversized bearings for longer pump life.
- C. Casing and internal parts: Impellers, diffusers, stage casing, discharge and suction casing as well as balance piston shall be ASTM 316.
- D. Pump Shafting: The pump shaft and impeller shall be supported by ball or roller bearings. Shafting shall be stainless steel ASTM 420 and shaft sleeve made by stainless steel ASTM 316.

Stuffing Box: The stuffing box shall be ductile cast iron. The stuffing box shall be designed to accommodate the mechanical seal.

- F. Seal: Balanced mechanical seal. The seal shaft sleeve shall be 316 SS. Mechanical seal materials shall be with Graphite/silicon carbide faces. Seal shall be positively driven by set-screws. Elastomer shall be of Buna N, and stationary seal member shall be of the cup-mounted type to ensure cushioning of face material from mechanical shock.
- G. Bearings: Shaft thrust in both directions shall be taken up by two back-to-back mounted single-row angular contact ball bearings. Roller bearings shall be provided for radial loads. Bearings shall be rated with a minimum B10 bearing life of 100,000 hours at the operating point.
- H. Bearing Housing: Shall be cast iron, and machined with piloted bearing fits for concentricity of all components. Bearing housing shall have oil bath lubrication or grease. Fill and drain ports shall be provided.
- I. Shaft Coupling: Bearing housing and motor stool design is to provide accurate, self-aligning mounting for an IM B3 electric motor. Pump and motor coupling shall be flexible elastomeric type.
- J. Stainless Steel Nameplates: Shall be attached to the pump and drive motor giving the manufacturer's model and serial number, rated capacity, head, pump and motor speed and motor horsepower.
- K. TECHNICAL DATA OF PUMPS AND MOTORS
- Hydraulic efficiency: $\geq 70\%$
 - Duty point NPSH: ≤ 2
 - Values according to ISO 9906/Grade 2
- L. Drive Motor: Three phase squirrel cage induction motors, shall be 355kW, 1480 RPM, 400/690 volts, 50 hertz, IM B3 mounted, protection IP55, insulation class F, temperature rise B, efficiency class IE2. Material of the motors must be cast iron, according EN60034-30. Bearings should be SKF/NSK. The motor shall be sized for non- overloading conditions.

G.37.14 Submersible Pumps

G.37.14.1 Pump Design

The pumps are automatically and firmly connected to the discharge connection, guided by two parallel guide bars extending from the top of the station to the wet well mounted discharge connection. Sealing of the pumping unit to the discharge connection is accomplished by a machined metal to metal contact. The entire weight of the pump/motor unit is borne by the pump discharge elbow. No portion of the pump/motor unit bears on the sump floor directly or on a sump floor mounted stand.

G.37.14.2 Pump Construction

Major pump components are made of grey cast iron ASTM A-48 Class 35B, (DIN 1691, GG25) with smooth surfaces devoid of blow holes or other casting irregularities. All exposed nuts or bolts are made of AISI type 304 stainless steel. All metal surfaces coming into contact with the pumped media, other than stainless steel, are protected by a factory applied water-based primer and finally covered by a two-component high-solid top coating.

Sealing design incorporates metal-to-metal contact between machined surfaces. Pump/Motor unit mating surfaces where watertight sealing is required are machined and fitted with Nitrile rubber O-rings.

No secondary sealing compounds, elliptical O-rings, grease or other devices are used.

G.37.14.3 Volute

Pump volute is a single-piece grey cast iron, Class 35B (DIN 1691, GG25), non-concentric design with smooth passages large enough to pass any solids that may enter the impeller.

G.37.14.4 Impeller

The impeller is made of grey cast iron, Class 35B (DIN 1691 GG25), dynamically balanced, multiple vaned, double shrouded non-clogging design having long throughlets without acute turns. The impeller is capable of handling solids, fibrous materials, heavy sludge and other matter found in wastewater. Mass moment of inertia calculations are provided by the pump manufacturer upon request. Impeller is keyed to the shaft, retained with an expansion ring and is capable of passing a minimum 88 mm diameter solid. Impeller is coated with alkyl resin primer.

G.37.14.5 Cooling System

Motor is dimensioned to be sufficiently cooled by the surrounding environment or pumped media. Cooling jacket or external cooling system is not required.

G.37.14.6 Wear Rings

A wear ring system is used to provide efficient sealing between the volute and suction inlet of the impeller. Each pump is equipped with a Nitrile rubber coated steel insert that is drive fitted to the volute inlet.

This pump also has a stainless steel impeller wear ring heat-shrink fitted onto the suction inlet of the impeller.

G.37.14.7 Pump Shaft

Pump and motor shaft is a solid continuous shaft. The pump shaft is an extension of the motor shaft. The pump shaft is made of carbon steel and is completely isolated from the pumped liquid.

G.37.14.8 Mechanical Seal

The bottom of the oil housing is shaped in such a way that it traps particles in its spiral track and then carries them out of the seal chamber by harnessing the energy of the rotational flow. This completely eliminates wear on the wall of the seal chamber, as well as considerably reducing seal face wear.

Each pump is provided with a tandem mechanical shaft seal system consisting of two totally in-dependent seal assemblies. The lower seal is independent of the impeller hub.

The seals operate in an oil reservoir that hydrodynamically lubricates the lapped seal faces at a constant rate. The lower seal unit, located between the pump and the oil chamber, contains one stationary and one positively driven rotating corrosion resistant cemented carbide ring. The upper seal unit, located between the oil chamber and the motor housing, contains one stationary seal ring and one positively driven rotating corrosion resistant cemented carbide seal ring. Each seal interface is held in contact by its own spring system. The seals require neither maintenance nor adjustment and are capable of operating in either clockwise or counter clockwise direction of rotation without damage or loss of seal function.

Should both seals fail and allow fluid to enter the stator housing, the fluid does not come into contact with the lower bearings, or the stator.

Each pump is provided with an oil chamber for the shaft sealing system. The oil chamber is designed to prevent overfilling and to provide oil expansion capacity. The drain and inspection plug, with positive anti-leak seal is easily accessible from the outside. The seal system does not rely upon the pumped media for lubrication.

G.37.14.9 Bearings

The pump shaft rotates on grease-lubricated bearings. The upper bearing, provided for radial forces, consists of a single roller bearing. The lower bearings consist of one roller bearing for radial forces and one angular contact ball bearing for axial thrust.

The lower bearing housing includes an independent thermal sensor to monitor the bearing temperature. If a high temperature occurs, the sensor activates an alarm and shuts the pump down.

G.37.14.10 Motor

The pump motor is induction type with a squirrel cage rotor, housed in an air filled watertight chamber. The stator windings and stator leads are insulated with moisture resistant Class H insulation rated for 180 oC. The stator is trickle impregnated with Class H resin and is heat-shrink fitted into the stator housing. The motor is specifically designed for submersible pump usage and designed for continuous duty pumping media of up to 40 oC (104 oF). The motor is designed for 15 starts per hour.

Thermistors are embedded in the stator lead coils to monitor the temperature of each phase winding. These thermistors are set to open at 140 oC and are used in conjunction with and supplemental to external motor overload protection and are connected to the control & status monitoring unit.

The motor has a voltage tolerance of plus or minus 10%. The motor is designed for operation up to 40 oC (104 oF) ambient and with an average temperature rise of the stator windings not to exceed 80 oC. A performance chart is provided showing curves for torque, current, power factor, input/output kW and efficiency. This chart also includes data on starting and no-load characteristics.

G.37.14.11 Junction Box

The junction chamber contains two distinct and separate terminal boards. One terminal board is used for the connection of the pilot sensor leads with the pilot sensor cable.

A separate terminal board is utilised for the line power connection to the motor stator leads. This power terminal board uses threaded compression type binding posts to connect the cable conductors and motor stator leads. The power terminal board separates and seals the junction chamber from the stator housing.

The cable entry junction chamber and motor is separated by a feed through type terminal board of non-hygroscopic material, which isolates the stator housing from foreign material gaining access through the pump top.

G.37.14.12 Power and Monitoring Cable

The power cable is sized to the IEC standards and is of sufficient length to reach the junction box without the need of any splices. The outer jacket of the cable is made of oil resistant chloroprene rubber with low water absorption, and with mechanical flexibility to withstand the pressure at the cable entry. The motor and cable is capable of continuous submergence without loss of watertight integrity to a depth of at least 20m.

G.37.14.13 Cable Entry Seal

The cable entry seal design precludes specific torque requirements to ensure a watertight and submersible seal. The cable entry consists of dual cylindrical elastomer sleeves, flanked by washers, all having a close tolerance fit against the cable and the cable entry. The sleeves are compressed by the cable entry unit, thus providing a strain relief function. The assembly permits easy changing of the cable.

G.37.14.14 Protection

The stator incorporates three thermistors in series to monitor the temperature of each phase winding. Should high temperature occur, the motor stops and an alarm is activated.

A lower bearing temperature sensor is provided. The sensor directly contacts the outer race of the thrust bearing providing for accurate temperature monitoring.

Float switch leakage sensors are provided to detect liquid in the stator chamber and in the junction box.

A capacitive leakage sensor in the oil housing issues an alarm if water content reaches a certain concentration.

The thermistors, float- and capacitive leakage sensors and the lower bearing temperature monitor are connected to a control and status monitoring unit. The control unit is mounted in the control panel.

G.37.15 Progressive Cavity (Positive Displacement) Pumps

G.37.15.1 General

- A. Scope: Contractor shall furnish and install all labor, materials, equipment, appurtenances, specialty items, and services required for complete and operable Progressive Cavity Pumps as shown and specified in the Contract Documents.
- B. Equipment Coordination: To ensure that all the equipment are properly coordinated and will function in accordance with the requirements of the Contract Documents, the Contractor shall retain ultimate responsibility under this Contract for equipment coordination, installation, operation and guarantee.

G.37.15.2 Construction

A. Casing and Impeller. A1. Suction Casings (drive end) Casings shall be able to be rotated through 270 degrees to accommodate three possible port orientations. Where appropriate, suction casings shall be capable of being supplied with an access port near to the rotor head to allow for clearance of blockage if required. The port cover must be bolted in place – no quick release fasteners are permitted in the interest of safety. Casings to be supplied with suitable threaded connections to allow for priming and draining where required or the addition of pressure monitoring equipment. Materials of construction to be cast iron to specification BS EN 1561, grade EN-GJL-HB195 or equivalent. Where stainless steel is required, casings should be constructed from cast stainless steel to specification BS 3100, grade 316C16F or equivalent. Alternatively, fabrications are acceptable using 316L stainless steel conforming to BS EN 10088, grade X2CrNiMo17-12-2 or equivalent.

A2. Discharge Casing (non-drive end) Casings shall be supplied with suitable threaded connections to allow for priming and draining where required or the addition of pressure monitoring equipment.

Materials of construction to be cast iron to specification BS EN 1561, grade EN-GJL-HB195 or BS EN 1563, grade EN-GJS 400/18 or 420/12 or equivalent. Cast steel to BS3100, Grade A1 WCB is an acceptable alternative for high pressure applications where cast iron is not suitable. Where stainless steel is required, casings should be constructed from cast stainless steel to specification BS 3100, grade 316C16F or equivalent. Alternatively, fabrications are acceptable using 316L stainless steel conforming to BS EN 10088, grade X2CrNiMo17-12-2 or equivalent.

B. Pump Drive Train

B1. Drive Shaft This is to be of a plug-in design for direct connection to a geared motor or separate bearing housing as required. Connection should be by means of a single pin through the shaft. The shaft should be manufactured from stainless steel conforming to BS EN 10088 grade X12Cr13/X2CrNi18-9 or equivalent to resist corrosion and seizure onto the geared motor or bearing housing shaft. Where 316 stainless steel is required, the shaft should be constructed material conforming to BS EN 10088, grade X2CrNiMo17-12-2 or equivalent. Where a packed gland is specified, the area under the packing should be coated with hard chrome plate to a minimum thickness of 0.13mm (.005"). Hard chrome plate must not be used on shafts where mechanical seals are to be fitted.

B2. Coupling rod and Drive joints The design shall be based around the simple pin joint, utilising an articulating singular pin drive at each end of the coupling rod. The joints should be sealed utilising a suitably rated rubber sleeve retained by stainless steel straps and/or stainless steel sleeve. Coupling rod articulation angle shall not exceed 2.4 degrees. The coupling rod shall be manufactured in one piece from high strength steel conforming to BS EN 10277, grade 20NiCrMoS2-2 or equivalent and subsequently case hardened to achieve 650-800Hv. Through hardening is not permitted due to the risk of cracking and loss of toughness. Where stainless steel is required, the coupling rod should be designed to accommodate replaceable bushes at the drive ends to resist wear. The stainless steel coupling rod material should conform to BS EN 10088, grade X2CrNiMo17-12-2 or equivalent. The replaceable bushes shall be manufactured from ASTM A681, grade 01 tool steel or equivalent and subsequently hardened to achieve 710Hv. Bushes shall be an interference fit when assembled into the coupling rod. Bushes shall come with alignment marks to ensure correct assembly. The coupling rod drive pins shall be manufactured from high speed tool steel conforming to ASTM A600, grade M42 or equivalent and subsequently hardened to achieve to 860Hv. Joint lubrication shall be by synthetic oil or semi-fluid grease. The use of high viscosity grease and mineral oils is not permitted due to its inferior lubrication properties and subsequent affect on wear life.

C. Pumping element

Pumping element design should be based on the traditional single lobe rotor concept. This requires the rotor to be circular in cross section. The use of multi-lobe designs (such as 2/3, 2 in 3, Trilobe etc) are not permitted due to the relatively

poor wear, solids handling and suction performance of such designs when used in a pump design of this type. Such rotors can be identified by their elliptical shape in cross section.

C1. Rotor For abrasive applications, the rotor shall be manufactured in one piece from an alloy steel conforming to BS970, grade 708M40T/709M40T (ASTM A 322, grade 4140/4145) or equivalent. The rotor surface shall be coated with hard chrome plate to a nominal thickness of 0.25mm (.010”) at the scroll peaks (major diameter). The surface shall be polished to a minimum of Ra 1.6 um (63uin) to maximise stator wear life. For applications requiring stainless steel, the rotor shall be manufactured in one piece from 316 stainless steel conforming to BS EN 10088, grade X2CrNiMo17-12-2 or equivalent. If a wear resistant coating is required, the rotor surface shall be coated with hard chrome plate and the surface polished to a minimum of Ra 1.6 um (63uin) to maximise stator wear life.

C2. Stator The stator shall be a one piece construction, utilising vulcanised rubber, chemically bonded into a carbon steel tube. Rubber grade shall be selected to be chemically compatible with the pumped product. The stator assembly method shall be by spigot location into the pump casings, clamped in place by the use of high tensile steel tie rods spanning the stator length only. Suction casings shall remain un-disturbed and secure when stator removal is required. Extended length tie rods or similar that encompass the entire pump casing assembly are not permitted due to the safety risk associated with the instability of pump casings when removed during maintenance. Stators that are threaded on the end and require screwing into casings are not permitted due the contact of the pumped product with the stator rubber/tube bond interface and subsequent affect on integrity over time.

D. Gland Seal Unless otherwise specified or dictated by duty conditions, the gland seal shall consist of a single internally mounted bi- directional mechanical seal.

Metallic parts shall be manufactured from 316 stainless steel. Face materials should be Silicon Carbide.

The use of carbon on steel based face materials is not permitted due to relatively poor wear life. Seal design shall conform to the requirements of DIN24960. Packed glands are non-preferred and only specified for duties where the use of a mechanical seal is not recommended. E. Pump Primary Drive This should be by direct connection of the pump drive shaft utilising a positive location cross pin drive to a flanged mounted geared motor, rated at duty conditions to have a bearing life L10 (B10) of 10000 hours minimum and a load service factor of 1.0 minimum.

The use of an independent bearing housing with separate input shaft for connection of alternative drive types is also permitted where required. Independent bearing housings should be suitably rated to achieve a bearing life of L10 (B10) of 10000 hours minimum and be grease lubricated and sealed for life using rubber lip seals or equivalent.

G.37.16 Peristaltic Pumps

Heavy duty peristaltic pump with PVC connections and EPDM hose to allow for pumping of chemical (Ferric Chloride) solution.

The pumping action results from alternately compressing and relaxing a machined hose between the pump housing and the compressing shoes. The fluid ahead of the shoe is pushed towards the discharge while the rebounding hose behind the shoe draws more fluid in. With 100% compression at all times, the pump will not slip, providing metering accuracy and pressure performance. The pump shall have no pump seals, seats or valves. The fluid will only be contacting the inner wall of the hose .

The pump shall be directly connected with its drive via a planetary gearbox. The hose will be of heavy duty design constructed of layers of rubber reinforced by winding several layers of nylon cords.

The inner and outer layers are extruded.

The inner layer shall (in the case of Ferric Chloride), be EPDM.

After the hose is constructed, it should be then machined to allow for consistent capacity.

The manufacturer shall be ISO 9001 certified.

G.37.17 Chemical Metering and Dosing Pumps

Chemical dosing shall be by means of electrically driven metering pumps unless otherwise specified.

Metering pumps shall be of the plunger or progressive cavity type.

The effective range of the metering pumps shall be between zero and maximum with an overall repeatable accuracy within $\pm 3\%$. Output shall be adjustable through a steeples variable stroke mechanism in the case of plunger pumps and variable speed motor or gearbox in the case of progressive cavity pumps.

The metering pumps shall be manually adjusted, and shall be calibrated to allow setting at the required dosage. Dose adjustment shall be possible whilst the units are in operation. Accurate dosing shall be maintained down to 10% of the maximum dosing rate.

The Contractor shall consider the liquid to be pumped and select the materials of construction so as to avoid corrosion. Mechanical glands are generally undesirable but where unavoidable, shall be to the approval of the Engineer.

For metering pumps of the plunger type the materials in contact with the liquid shall be polypropylene, stainless steel grade 316, UPVC or PTFE. Plungers shall be a high-alumina ceramic or stainless steel, grade 316.

Metering pumps shall be mounted on bed plates which shall be protected from gland drip. The pumps shall be driven by close coupled motors with reduction gears and have mechanisms housed in a totally enclosed oil bath.

At least one standby pump, fully connected into the chemical dosing system, shall be provided for each chemical, with local manual selection of duty and standby units. When pump duty change-over is effected the appropriate suction and delivery isolating valves shall be manually operated.

Stators and rotors for progressive cavity pumps shall be of materials selected having regard to the liquids being pumped.

The design and location of the metering pumps shall be such as to facilitate easy dismantling for the removal of any foreign matter.

Flushing facilities shall be provided for all chemical pipe work at the inlet and outlet of each metering pump, together with drip trays to contain any spillage or leakage and piped to the nearest drain point. Provision shall be made for priming the systems to eliminate any air.

Each chemical dosing pump shall be provided with suitable isolating valves, an inter- connecting manifold system and, where necessary, loading valves. A calibrated glass container shall be provided connected into the suction manifold of each chemical pump so that its output can be checked.

Calibration curves shall be provided by the Contractor for all chemical dosing pumps.

G.38 Surge Suppression Equipment

Surges in pipelines are usually caused by opening, closing or regulating valves or pumps starting and stopping. These surges, also called hydraulic transients may range in importance from a slight pressure or velocity change to sufficiently high pressure or vacuum to rupture the piping system, to damage pumping equipment and cause extensive shutdown time.

G.38.1 Surge Analysis

Surge protection analysis will be performed on critical sections of the piping system to verify design and surge control equipment selection. If excess transient pressures are predicted by the analysis, design and mechanical equipment application will be modified. Hydraulic surge control is a specialized field. A detailed surge protection study is required, it should be provided by engineers or consulting engineering firms specialized in this field. Detailed pipeline surge analysis by an expert should be considered to find out appropriate surge control methods

G.38.2 Protection Tools

The most common devices to overcome the effects of excessive hydraulic surge pressures in water system:

- Pressure relief valves , spring loaded or pilot operated
- Surge anticipating valves & Pump Control valves
- Inline check valves with bypass
- Anti-shock air valves at critical summits and ascents
- Anti-slam check valves closing at low reverse velocities under high deceleration.
- Stand pipes
- Surge vessels , Standard hydro pneumatic or open one way

G.38.3 Poor Maintenance Requirement

Should a surge vessel is recommended as surge control the particular scenario of power failure with vessel out of service should be considered to check for additional backup protection against burst failure.

G.38.4 Allowable Negative Pressure

Sub atmospheric (Negative) pressures should not be allowed to form in a potable water pipeline as this may cause disintegration of the cement lining of pipes, suction of flanges gaskets and intrusion of contaminants, Air valves should also not normally be allowed to open under unsteady conditions due to negative pressures. The minimum pressures are generally limited to +0.2 bar above pipeline crest.

G.38.5 Allowable Positive Pressure: PMA

Installed fittings dictate pressure limit of pipeline PMA

PMA: permissible maximum operating pressure surge included

Flanged fittings limit PMA override normally limit of all others components, pipes & push-in fittings.

PFA: PN Flanged	PMA: Max Pressure
10 bar	12 bar
16 bar	20
25 bar	30
40 bar	48
64 bar	77

G.38.6 Cyclic Loading

A de-rating factor should be applied to PMA of metallic pipes & fittings in the instance of cyclic loading or high frequency of on/off operations, PMA and pressure rating of thermoplastic pipes should be re-calculated accordingly.

G.38.7 Surge Vessels

The Surge Vessel shall consist of a vertical steel tank mostly of bladder type, connection valves, pipes and all necessary appurtenances .

G.38.8 Vessel Design & Materials

The surge vessel shall be made of welded steel shells and dome ends according to European Directive DESP 97/23 CE and EN 13480 -3, EN13445 or ASME boiler & Vessel codes, section ASME VIII-1 / VIII-2 - Construction of Pressure Vessels, ASME II – Materials

G.38.9 Painting

Painting of surge vessel shall be in accordance with the standard EN ISO 12944 – 2007 and comply with the following requirements.

Internal coating – Food quality epoxy paint

External coating – 2 coats of epoxy

External coating colour shall be Sky Blue

G.38.10 Fittings and Instruments

Flange outlets, Inspection hole, Drainage plug, Glass tube levels indicator with an isolating valve,

Pressure gauge with isolating valve, Safety valve, Air inflation plug, supporting legs Lifting lugs

Air Compress, Magnetic level indicators

The Surge vessel shall be designed for anchor bolting to a concrete foundation. The supports shall be designed to withstand all natural loadings, any hydraulic and pneumatic thrusts resulting from surges.

Foundation design calculation shall also be submitted to the Engineer and get approval before construction.

G.38.11 Testing of Material

Manufacturing process shall comply all the material test procedures in the EN 13445 – part 2

- 2009 and the following final assessment tests described under EN 13445 part 5- 2009.
- Test on welds
- Dimensions check
- Inspection of safety accessories

G.38.12 Bladder Surge Vessel

A bladder surge vessel has the same function with regard to surge control as the traditional compressor vessel.

In a similar way to a vessel controlled by compressors, optimum pre-charge pressure results from detailed surge analysis.

The vessel can either be horizontal or vertical. It is constituted of a steel vessel containing a rubber bladder made from butyl or polyurethane (suitable for use with drinking water) and a flanged connection pipe equipped with anti-extrusion grill.

The vessels are treated internally sand blasted and coated with food quality epoxy paint as corrosion protection.

In order to verify the level in the vessel it is normally equipped with a level indicator as well as a manometer to verify the initial pre charge pressure.

The vessel will be equipped with a non-return valve with a bypass to mitigate backflow surge, if hydraulically required.

The bladder shall be made out of butyl or polyurethane complying BS 6920-2000 and shall be easily replaceable.

It shall be suitable and approved for use in drinking water systems. The bladder shall be perfectly watertight and airtight after the installation inside the vessel.

The tank, bladder and instrumentation shall carry a warranty of one year from delivery.

G.38.13 Air Compressor

The compressor shall be integrated units with vertical or horizontal tank and piston compressor aggregate mounted on the top and total product should be confirmed to ISO

1217 – 2009.

The compressor shall be compatible with the surge vessel specification, to create necessary pressure requirement for the above surge vessel.

The unit shall be equipped with pressure regulator, and suction filter, automatic pressure control of start and stop of the compressor aggregate, line circuit breaker and water trap.

Maximum allowed noise pressure: 70 dB @ 1m.

G.38.14 Control Equipment

Control equipment to provide fully automatic control of the selected duty compressor from the water level measuring instrument of the surge vessel.

Correction of air volume is preferred to be carried out under static state with idle pumps, switching on compressor should then override pumps energizing

For continuous pumping duty, a time delay shall be incorporated to prevent operation of the compressor during water level changes under surge conditions and a push button feature shall be provided for manual test of the system.

The front side shall have a full width door hinged with a rotating handle and positive closing action. The control panel shall include:

- One lock with a key
- Meters with selectors switches, HOURMETER/VOLTMETER/ANMETER.
- One switch START/STOP.
- Status indication ON/OFF/FAULT

- Contactors - (Starter).
- One differential thermal protection.
- Control circuit protection circuit breakers.
- One connection terminal (control and power).
- One PLC.
- The required relays for transmitting safety and system regulating data.
- A three pole isolating switch, with operating handle interlocked with the enclosure door.
- A water level control module.
- A non-latching motor test push-button.
- One selection switch LOCAL/REMOTE/ZERO

G.38.15 Fittings & Accessories

Each compressor shall be provided with the following features:

- Outlet pressure gauge.
- Pressure relief valve on each stage of compression.
- Suction filter with high separation capacity and silencer.
- Automatic unloading valve for a no-load start under all conditions
- Non-return valve.
- Protective guard between motor and compressor.
- Oil separator filter
- Filter and dryer for holding back solid and liquid particles of 5 microns.
- Pipe work

G.38.16 Cabling

Between the switchboard and the control panel

Between the control panel and the compressors

Between the control panel and the level electrodes on the surge vessel

Earthing of all equipment.

G.38.17 Sight Glass & Magnetic Level Indicator

The sight glass level indicator shall have the following characteristics:

- Operating pressure range: Vacuum - Max test pressure.
- No requirement for energy source.
- Pressure compensated floats to avoid float drowning.
- Magnetic coupling of the indicator elements.
- An excellent readability ensured by resistance against product contamination and UV rays.
- Corrosion resistant.

- Highest operational safety through separation of liquid & indicator display.
- No re-calibration required.
- High mechanical strength. The level indicator shall be equipped with magnetic switches and a continuous control elements and transmitter allowing remote monitoring of water level alarms and controls.

G.38.18 Surge Anticipation Valves

The valve shall be installed in a by-pass line immediately downstream of the pump(s) and the check valve. The surge anticipation valve shall be interlocked to the pump(s) via the three-way solenoid valve that shall be supplied with the valve.

The basic valve shall be a single-seated, line-pressure-operated, diaphragm - actuated, pilot controlled globe or angle valve. The valve shall seal by means of corrosion - resistant seal and resilient, rectangular seat disc. These and other parts shall be replaceable in the field; all such service and adjustments to be possible without removing the valve from the line.

The stem of the basic valve shall be guided top and bottom by integral bushings. The basic valve and its pilot control system shall contain neither packing glands nor stuffing boxes.

The diaphragm shall not be used as a seating surface nor shall pistons be used as an operating medium. All internal and external ferrous surfaces shall be coated with a high quality, two-part epoxy primer; the exterior to receive a coat of backed enamel paint.

The pilot control system of the valve shall consist of a three-way solenoid controlled pilot- valve, an accumulator, a three-way diaphragm actuated pilot valve, an adjustable needle valve for opening speed control, an adjustable needle valve for closing speed control and a “Y” strainer. To isolate the control system from the main valve, inlet and outlet ball stop valves shall be provided.

- Temperature ratings: 0 °C - 85 °C
- Maximum pressure differential across the diaphragm of the basic valve must not exceed 20 bars.
- Valve materials [Pressure Ratings]:
- Cast iron - ASTM A126/B [< 25 bars]
- Forged or Cast steel - ASTM A126/WCB [> 25 bars] Cast bronze - ASTM B61, B62 [16 - 35 bars]
- Cast aluminum 356 - T6 [< 20 bars] or equivalent International Standards.
- Stem: Stainless steel/Ductile iron
- Seat Ring: Cast bronze or stainless steel
- Electrical Power: AC, 50HZ, in 110/220 volts / DC 6, 12, 24, 120, 240 volts.

G.39 Lifting & Handling Equipment

G.39.1 General

Cranes and hoists shall be of standard proven design in accordance with BS 466, rated for lifting the specified working loads, utilization and service conditions and shall be suitable for operation from the runway beams provided. Motions shall be motorized as specified with dual speed hoisting facility and controlled from a pendant push button unit via a crane control panel mounted on the gantry.

All operations, whether manual or electric, shall be controlled or performed from motor room floor level unless otherwise specified.

The lifting assembly shall be rated for the highest lift that could occur during installation and maintenance operations, including allowance for stiction.

The crane shall consist of a gantry or jib, crab and hoist assembly, ropes, block and hook together with the necessary running rails and all electrical supply requirements.

Chains used for lifting or travel shall be alloy steel and corrosion protected by an electro- deposited, zinc coated finish after manufacture. They shall not be hot-dip galvanized.

The load chain anchorage, associated fittings and framework at the slack end shall be at least equal in strength to 2.5 times the maximum tension in the load chain when the working load limit is being lifted. Any links used for connecting the load chain to a terminal fitting shall be the material specified for the chain and heat treated to provide mechanical properties and strength equivalent to those of the load chain. The hook shall be made from high grade forged steel complying with BS 2903 "C" type, and provided with a safety catch. The safe working load shall be marked.

Jibs or gantries shall be of plate or box girder design and securely attached to end mountings or carriages.

A reliable braking and locking arrangement shall be incorporated and a load chain collection box shall be incorporated with the crab.

G.39.2 Cross Travel and Long Travel

End carriages for gantries shall be fabricated from rolled steel plates and have two, double- flanged, cast steel wheels to match the track rails. Where rails are supplied and installed under this contract, they shall be adequately supported throughout their length to carry all the dynamic and static loads imposed by the crane duty.

Crab assemblies shall be mounted on four flanged cast steel wheels to suit the jib runway beam or cross-travel rails fixed to the main crane gantry.

Each travel range shall be the maximum permitted by the building and runway constraints. Where applicable the extent of each travel motion shall be limited by electrical limit switches with mechanical end stops secured to the travel rails beyond the electrical limit switch positions, to prevent overrun and building damage from swinging loads mechanical end stops shall also be provided where travel is by manual operation.

In the case of electric motor driven travel two travel speeds shall be provided. The fast speed shall not exceed 16m/min and the slow speed not exceeds 4m/min. These drives shall always start at the lower speed and incorporate smooth acceleration and deceleration controls.

G.39.3 Hoist

The hoist unit on travelling beams shall be mounted to provide the highest possible lifting facility whilst maintaining adequate clearance between the crab/hoist assembly and the building structure and fittings.

Hoist units fitted to single runway beams, fixed or jib mounted shall be of the self-suspension type mounted on a single rigid trolley suitable for manual geared travel along the runway beam. Two end stops shall be provided on the beam suitable for the trolley provided. The trolley shall have ball or roller bearings grease packed for life.

The hook shall be fitted with a swivel and a safety catches and is capable of touching the floor and providing a minimum lifting height as specified.

In the case of electrically operated hoists the normal hoist speed shall be approximately 4 min/min and the creep speed shall be approximately 600mm/min or nearest standards. An overload device and overwind limit shall be included to prevent dangerous overloads. Raise and lower limit switches shall be provided at the maximum and minimum lift positions. Instantaneous fail safe braking in the event of power failure shall be provided.

Where operation is by electric motor a power supply shall be provided under the contract. Power shall be taken from a feed in the main distribution panel forming part of the works and a wall mounted fused isolator shall be provided at a suitable location approximately 1.5 m above floor level alongside the lifting installation.

Power transmission to the moving installation shall be by pick up shoe running along the underside of shrouded rails, suspended concertina cable running on slides or a rail or a cable from a self winding cable reeling drum. In the latter case the tension in the cable shall be controlled and supports provided to prevent the cable drooping more than one meter below the crane rail (s).

G.39.4 Rating Plates

The SWL shall be clearly marked in Local and English language on the rating plate and shall be legible from the plant working level.

G.39.5 Paint Finish

The finish colour shall be a full gloss Yellow Color No. 356 to BS 381C or equivalent reference 08 E 51 to BS 4800.

G.39.6 Crane Access

Where clearances permit, provision for safe access for maintenance shall be provided in accordance with BS 466 and shall include a walkway across the span having a height clearance of 2m and be fitted with double-tiered handrails and toe boards.

An extending, portable aluminium ladder shall be provided for access to the crane for maintenance etc.

G.39.7 Crane Controls

The electrical controls shall be designed to prevent excessive acceleration, retardation, skidding and load swinging and all motions of the crane shall be arranged to be switched through the slower speed where provided.

The control circuits for the crane/hoist shall operate at not more than 110V and be derived from a double wound, screen earthed isolating transformer with one side of the secondary winding connected to neutral/earth. The primary supply shall normally be from the phase conductors.

Fuses shall be provided on each primary and secondary supply and be clearly labeled and segregated. A link shall be fitted in the neutral/earth connection.

G.39.8 Control Panels

The crane control panels shall be constructed of sheet steel or other approved material and shall be hose proof (IP65).

The control panel shall be mounted on the travelling crane hoist bogie in a convenient position for inspection and maintenance, and shall house all the fuses, motor protection devices, starters and control equipment for controlling the

crane/hoist. All contactors shall be of the air-break, electrically operated hold-on type with all necessary auxiliary contacts. Reversing contactors shall be mechanically and electrically interlocked to prevent conflicting operations.

The panel shall be fitted with a main isolating switch interlocked with the door to allow access only when the switch is open.

The motor starters shall be provided with adjustable overload protection devices suitable for the motor load at each speed and having manual resetting facilities within the panel.

All control equipment shall be fitted with suitably rated fuses. Fuse ratings shall be rationalized as far as possible to limit spares. Where practicable, fuses shall be housed in all- insulated carriers with fully shrouded bases.

Fuse links shall be HRC cartridge type to BS 88, Class Q1, having provision for screw fixings for attachment to the carrier.

G.39.9 Pendant Controls

A heavy duty, industrial pattern pendant push-button control station shall be provided, having sets of non-maintained push-buttons for each hoist speed and function specified.

Each set of buttons shall be electrically and mechanically interlocked so that conflicting operations are prevented and only one function can be initiated at one time.

The push-button enclosure shall be of a tough neoprene rubber suitable for withstanding arduous duty and provide full electrical safety, each button being suitably labelled with its function. It shall have an IP55.

The pendant shall be divorced from the crab and capable of independent cross travel. It shall be suitable for vertical adjustment for operation from alternative levels by means of spring loaded reeling drum fitted with a ratchet device or motor driven reeling drum and have a cable guide runner to assist re-coiling.

Pendant control cables shall be designed for reeling drum application and have stranded copper flexible conductors, EPR insulated to 300/500V, multi cores laid-up with an internal central textile strain carrier and heavy duty, textile braid reinforced, PCP sheath.

For non-reeling applications, the outer sheath may be flexible PVC, incorporating externally laid, galvanized steel, nylon coated strainer wires.

G.39.10 Radio Control

Where specified, the crane remote control shall be by means of radio transmitter and receiver units operating within the UHF waveband range approved by the relevant authority. The receiver shall be accommodated on the crane in a metal enclosure to IP55, having shock absorbing, rubber mountings, an external receiving aerial and incorporate an output relay for each transmitter function.

The transmitter shall be a lightweight, hand held device enclosed in a heavy duty impact resistant enclosure to IP67 complete with a bandoleer carrying strap.

The unit shall be powered by rechargeable batteries having capacity for 10 hours continuous operation on fully charged batteries. To conserve battery life, a 'time out when not in use' function shall be incorporated and the stop button shall be fitted with a key switch to prevent unauthorized use. All push buttons shall be spring returned to the 'off' position and interlocked to prevent conflicting operations. Programmable security coding shall prevent operation from unwanted signal interference.

A suitable wall mounted, metal enclosed charger shall be provided to enable the transmitter to be connected and maintained in a fully charged condition when not in use.

G.39.11 Flexible Cable Systems

The supply to the crane for both cross travel power together with pendant cross travel connections, shall be by flexible round or flat-form cable systems suspended on trolleys sliding in galvanized track from the crane structure.

The trolleys shall be formed from stainless steel side plates and axles with nylon runners. Sufficient trolleys shall be provided to effect a maximum cable loop of 0.5m.

The cables shall be PVC insulated and flexible PVC sheathed type designed for the application, incorporating flexible stranded copper live and earth conductors, terminated in suitable junction boxes as specified with weatherproof glands designed for the cable shape.

G.39.12 Bus Bar Collector System

The power supply and earth connection for the long travel shall be from a current collector system of fixed busbar conductors which shall each be fully shrouded with PVC covers suitable for outdoor use.

The conductors shall be suitable for the current capacity, voltage drop and temperature conditions for the installation. Current collectors shall be of the sliding contact type with insulated contact heads mounted on spring loaded trolley arms. No current carrying surfaces shall be exposed.

G.39.13 Cable Reeling Drums

Cable reeling drums shall be of the spring loaded type which coils the cable radially about the drum axis and arranged for direct pulling off the drum, the core diameter being not less than the minimum bending radius of the cable. The springs of the drum shall be adequately rated to reel the useable length of cable fitted with the maximum tension applied shall not exceed the cable makers recommendation. Motor driven reels shall be provided where the spring loading is excessive.

The cable shall not overheat when used with the cable fully retracted. A totally enclosed slip ring connection box suitable for the incoming supply cable, shall be fitted and the slip rings shall be rated to carry the full load current continuously and be accessible for maintenance.

Where specified, anti-condensation heaters shall be provided in the slip-ring will be enclosure, supplied at 240V AC or less from the appropriate slip rings via a fuse and link which shall be accessible without removal of the slip ring housing.

G.39.14 Trailing Cable

The trailing cable shall be 450/750V grade multi core type, designed to be suitable for use with a reeling drum. The size of the cable shall be such that a maximum recommended tension that may be applied to the cable is not less than the tension produced by the reeling drum.

Conductors shall be of flexible stranded copper, vulcanized rubber insulated with numbered tapes over each core. They shall be formed in a short lay round a flexible non-conducting centre core, sheathed overall with a textile covering and heavy duty PCP sheath.

Cable conductors shall be not less than 2.5mm² and sized so that they will carry the maximum full load working current involved without excessive voltage drop and take account of thermal de-rating in accordance with the IEE Regulations, as applicable to the particular drum and mode of cable winding.

In addition to any supply, control, or motor feed cores, the cable shall contain an earth core of size not less than that of the largest phase conductor.

NB Cable material descriptions: PVC Polyvinyl chloride (BS 6746) EPR Ethylene propylene rubber (BS 6899) CSP Chlorosulphated polyethylene PCP Polychloroprene (propylene/chlorosulphated polyethylene)

G.39.15 Rail Bonding

Each section of running rail on the side adjacent to the supply isolator shall be bonded together and the rail connected to the earth terminal on the supply isolator by a protective earth conductor having a conductivity not less than that provided by a 4mm² section copper cables. The rail bonds shall be made by either of the following methods:

- 1) Each section of rail is to be drilled near its end with a 7mm (9/32") hole. An 8 SWG steel wire bond, galvanized to grade GLS400 to BS 182, is to be connected across each joint and secured at each end into the hole in the rail section by means of a tinned tapered steel pin which has a semi-circular groove along its length to hold the wire. The wire is to be over length and the excess taken up by forming the wire into a 'Z' shape to absorb the expansion.
- 2) For indoor locations, an over length, 4mm² section of tinned copper braid, fitted with crimped lugs at each end shall be bolted to each rail end by means of brass bolts and washers of not less than 6mm diam.

G.40 Testing

G.40.1 General

The whole of the plant covered by this Contract shall be subject to inspection and witness testing by the Engineer during manufacture, erection and on completion. The cost of the tests and inspection shall be borne by the Contractor. The Engineers costs for attendance of retesting due to failure of the plant, or inappropriate preparation by the Contractor with respect to initial tests, shall also be borne by the Contractor. This shall not include the Engineers costs for attendance of the initial tests.

The Works shall also be subject to testing after completion throughout the defects notification period to an approved Test Plan. The Contractor shall provide guidance to the Employer for the sampling regime and tests to be undertaken. The Contractor shall attend the tests undertaken and his representative(s) shall have relevant experience with conducting such tests and the interpretation of the results obtained. The costs associated with the attendance shall be borne by the Contractor:

- Particular plant/equipment tests specified under the following clauses shall not be considered as being comprehensive or limit the requirements that the whole of the plant shall be tested at the stated Contract stages.
- Before the plant is packed or despatched from the Contractor's or Sub-Contractor's works, all tests called for shall have been successfully carried out and the required copies of the results submitted to the Engineer.
- The Contractor shall submit for approval a Test Plan covering all stages of inspection and testing for all items of plant. The Plan shall include full details of inspection/test methods and procedures together with appropriate schedules to record all results. No inspection or testing shall take place until the Plan is approved. The

inspection/test schedules shall be completed at each stage showing full results of all inspections/tests and shall be signed off by all parties.

- The Contractor shall be responsible for the submission to the Engineer of all plant in his supply for site inspection and test as required by the Engineer. During the course of erection, the Engineer shall have full access for inspecting the progress of the work and checking its accuracy as may be required. On completion of erection, all pressure parts shall be subject to a suitable hydraulic test and running tests on all plant shall be carried out by the Contractor witnessed by the Engineer to demonstrate adequately that the equipment as erected on site is entirely suitable for commercial operation.
- The Contractor shall also carry out tests on existing equipment, which is to be associated with Plant supplied under this Contract, to ensure that the equipment and connections operate correctly in conjunction with the Plant.

G.40.2 Testing at the Manufacturer's Works

- Works test shall include electrical, mechanical and hydraulic tests in accordance with the relevant standards and in addition, any tests called for by the Engineer to ensure that the plant being supplied fulfils the requirements of the Specification. For plant not covered by any Standard, or by the Specification, the test shall be agreed with the Engineer:
- The Contractor shall be responsible for arranging witnessed tests at the manufacturers works and for ensuring compliance with the Specification, satisfactory finish, workmanship etc. Simulated tests shall be carried out as necessary.
- Plant shall be offered to the Engineer for testing in his presence.
- A test procedure shall consist of a logical step by step schedule indicating step, test, reaction along with test results/measurements.
- Before testing at the manufacturer's premises is undertaken, the Contractor shall submit for discussion and consent no less than 30 days prior to the test date his Test Procedure an Acceptance Testing Documentation so that all parties may be fully conversant with the methods to be adopted in demonstration and proving of the plant.
- If it is necessary to provide simulated controls in order to perform a test at the manufacturer's works, he shall provide such controls as part of the works. The design of the controls shall be subject to prior consent by the Engineer.
- The Contractor shall give 30 days' notice in writing to the Engineer when equipment is ready for test at the manufacturer's works.
- Any means of interlocking along with alarm and fault detection provided by the equipment shall be validated. This will involve making provision for inducing a sufficient variety of faults and out-of-range conditions in the system to ensure the interlocking and detection processes are adequately tested. Similar requirements shall apply to the validation of status signals.
- The above tests shall be satisfactorily completed, and the required test documentation submitted to the Engineer, before the Contractor is permitted to start delivery and installation, without in any way relieving the Contractor of his responsibility for the correct operation of the equipment when it is installed on site.

G.40.3 Testing of Pumps

Pumps, irrespective of application shall undergo a full Pump Test as applicable.

The medium used for testing shall, if possible, be the same as that pumped by the pumping plant in normal service.

All pumps shall be witness tested, with the respective drive motor provided under the contract.

The tests shall prove that the respective pump can achieve the specific duty points and operating range as required.

Guaranteed efficiency is required at the duty point(s) or at selected points in the duty range if variable speed units are being provided.

The combined pump and motor efficiencies quoted in the Contract shall be achieved.

Rotary pumps shall be performance tested using clean cold water in accordance with ISO 3555 for water supply pumps.

Site conditions shall be simulated as near as possible including the NPSH condition. Pumps shall be tested with their own prime movers. Where it is impracticable to include the full length of the connecting shaft, the Contractor shall state the allowances to be made for the losses incurred by its omission and shall demonstrate the accuracy of the allowances to the satisfaction of the Engineer.

Special pumps (i.e. those for which the impeller is specially designed) shall be tested to prove the duty/guarantee point and to develop Quantity/Head, Quantity/Power, Quantity/Efficiency curves for the pump at the stated operating speed. If the pump is multi or variable speed the above performance shall also be developed at maximum and minimum speeds.

Mass produced pumps shall be tested to prove the duty/guarantee point.

All pump casings, and other pressure components, shall be hydraulically tested before assembly to a pressure of 2 times the maximum operating head of the pump

In addition to confirming the specified hydraulic performance of the pump set, the test shall demonstrate that vibration is within the specified limits and that the mechanical performance is satisfactory.

A test report including the items detailed below shall be submitted to the Engineer at the conclusion of each test:

- (a) place and date of the acceptance test; (b) manufacturer's name, type of pump, serial number; (c) specification of the pumps drive; (d) duty point(s); (e) description of the test procedure and the measuring apparatus used including calibration data; (f) observed readings presented in tabular and graph format; (g) evaluation and analysis of test results; and (h) conclusions.

G.40.4 Testing of Air Blowers and Compressors

All air blowers and compressors shall be witness tested, with the respective drive motor provided under the Contract, at the manufacturer's works.

Air Blowers shall undergo their manufacturer's standard tests and the following particular tests:

Blower casings shall be hydrostatically tested.

The test pressure shall be at least 1.5 times the maximum allowable working pressure. Leaks, distortions or instability during the test period shall render the tested equipment unacceptable.

The test shall last sufficiently long to allow a complete examination of the pressurised parts.

The minimum period at the test pressure shall be 30 minutes;

The blowers shall undergo a 4-hour performance load, running test. The test shall be a simulation of the rated conditions.

The blower shall be tested simulate the duty operating mode.

During the test and the delivery flowrate, delivery pressure, and inlet pressure shall be monitored and recorded.

Auxiliary systems such as cooling water and lubricating oil shall also be monitored and recorded.

Correction factors and associated calculations shall be stated in the Contractor's test procedures;

and

All blowers shall be dynamically balanced and subjected to vibration testing.

The performance tests shall be in accordance with:

- 1) ISO 1217 for positive displacement blowers and compressors. 2) ISO 5389 for centrifugal blowers.

G.40.5 Testing of Gate Valves

Gate valves shall be tested in accordance with Hydraulic test according to EN 1074-1 and 2 / BS 5150 / BS 5163 as relevant. In either case, valve seat tests shall be made under open-end conditions, the test pressure being applied to each face of the valve in turn.

G.40.6 Testing of Butterfly Valves

Butterfly valves shall be tested in accordance with BS 5155. The sea test shall be for tight shut-off and low leakage. Valves shall be tested under maximum unbalanced water test pressure in either direction.

G.40.7 Testing of Resilient Seated Double Eccentric Offset Flange Butterfly Valve

This type of butterfly valves shall be tested in accordance with EN12266-1 Leak rate A for tightness. The test shall be for tight shut-off and low leakage. Valves shall be tested under maximum unbalanced water test pressure in either direction.

G.40.8 Testing of Air Valves

Air valves shall be water tested for drop-tightness at all pressures from 0.2 bar in steps of 2 bar up to the specified pressure. The valve body shall be water tested at 1.5 times the specified pressure, at which pressure no damage or permanent deformation of the valve body, ball or seat shall occur.

Two valves of each type and size incorporating large orifices shall be tested for exhaust of air at a differential pressure up to 1 bar in steps of 0.1 bar and for inflow of air at a differential pressure up to 0.5 bars in steps of 0.1 bars. During the tests the airflow rates shall be measured by orifice plates in accordance with BS 1042. Pressures (positive or vacuum) shall be measured by Bourdon tube gauges or by means of mercury-in-glass manometers. The temperature of the flowing air shall be measured in accordance with BS 1041: Part 1 and Part 2. The barometric pressure shall also be measured.

If the manufacturer provides results of independently witnessed airflow tests similar to those specified and these are accepted by the Engineer, then the specified airflow tests shall be deemed to be completed.

G.40.9 Testing of Check Valves

Check valves shall be tested in accordance with the requirements of DIN EN 1074 for water / BS 5153 .

G.40.10 Testing of Pressure and Flow Control Valves

Pressure and flow control valves shall be tested hydrostatically as follows:

Body strength: closed-end test, valve open, test pressure 1.5 times working pressure. Leak tightness: open-end test, valve closed, test pressure of the working pressure applied to inlet end, no visible leakage permitted.

G.40.11 Testing of Ball Float Valves

Ball float valves shall be tested hydrostatically in the closed position and a pressure of 1.5 times the working pressure applied to the inlet end.

Valves shall be tested for drop-tightness at the working pressure.

G.40.12 Testing of Plug Valves

Plug valves shall be subject to hydrostatic shell and seat tests in accordance with BS 5158.

G.40.13 Testing of Penstocks

Penstocks shall be operated from fully closed to fully open positions to verify correct operation. For penstocks fitted with power-operated mechanism, the test shall be carried out to demonstrate correct manual and power operation.

A leakage test shall be carried out to prove the penstock is drop tight under seating and unseating conditions.

The penstocks will be water tight under the operating pressure and flow direction conditions at the specific operation point (on seating and off seating). The allowed leakage from the sealing area will not exceed the requirements of DIN 19569-4 and especially:

- Channel Penstocks (sealing from 3 sides) with a maximum leakage rate of 6 L/min per linear meter of sealed perimeter, under water.
- Wall mounting (sealing from 4 sides) with a maximum leakage rate of 3 L/min per linear meter of sealed perimeter, under water

G.40.14 Testing of Electric Actuators

Electric actuators shall be tested in accordance with the Reference Standards. Compliance with the specified functional and performance criteria shall be demonstrated.

G.40.15 Testing of Pipework

Pipe work shall be tested in accordance with the appropriate Reference Standards.

G.40.16 Testing of Castings

Castings shall be tested hydrostatically to 1.5 times the maximum working pressure for a minimum period of 1 hour.

G.40.17 Testing of Surge Vessels

Surge vessels shall be tested in accordance with the Reference Standards.

G.40.18 Testing of the Chlorination System

The tests on completion of the chlorination system shall include the following:

- 1) Injection rate
- 2) Injection pressure
- 3) Absence of leaks
- 4) Injected concentrations
- 5) Compliance with specification
- 6) Safety criteria
- 7) Such other tests as the Engineer may determine.

G.40.19 Testing of Lifting Equipment

Before lifting equipment is used for any purpose whatsoever it shall be tested to lift and maintain a minimum test load of 125% of the safe working load. During this overload test each movement in turn shall be manoeuvred and the equipment shall sustain the load under full control.

The Contractor shall provide the necessary test loads and carry out the tests on all the equipment he has supplied.

The tests shall be carried out in the presence of the Engineer, who may require to measure deflections or make other observations during the tests. The tests may also need to be witnessed by others.

G.40.20 Testing of Automatic in-line Strainers

Automatic in-line strainers shall be tested in accordance with the Reference Standards and with manufacturer's own requirements.

G.40.21 Tests at Site

The Contractor shall submit to the Engineer detailed proposals for testing. The proposals shall give values of test parameters and make reference to standards and manufacturers' literature. The proposed format of test sheets shall be submitted at the same time. A separate sheet shall be used for each test. The testing shall not commence until the proposals and test sheets have been approved in writing by the Engineer.

The following inspections and tests shall be carried out as appropriate:

- Inspection to check the assembly of the Plant and conformity with the Specifications.
- Checking of all electric motors.
- Hydrostatic testing of all gravity flow pipe work systems and penstocks at the maximum head or differential head that can occur in service.
- Leakage from penstocks shall be measured and recorded but shall not exceed the maximum value stated in the Contract or otherwise required for safe operation.
- Hydrostatic testing of all pressurized pipe work systems at 1.5 x maximum working pressure for a period of at least one hour.
- Performance testing of each pump to prove correct operation, absence of fluid leaks, correct bearing temperatures and absence of undue vibration and noise.
- Functional testing of auxiliary items including automatic in-line strainers and valve actuators.
- Functional testing of valves to demonstrate correct operation.
- Overhead cranes shall be tested with a load of 1.25 x Safe Working Load and results recorded in accordance with the Reference Standards.

G.41 Chlorination Equipment and System

This Section covers the supply, installation, testing and commissioning of a complete gas chlorination system for disinfection at water treatment and pumping facilities. Disinfection shall be accomplished by chlorination using a chlorine gas cylinder system. The Contractor shall provide complete systematic works for pre- and post-chlorination systems, including storage and handling of chlorine.

The Contractor shall provide and install chlorine gas handling equipment and all appurtenant works, complete and operable, including all necessary cylinders, controls, valves, piping, gauges, switches, regulators, safety devices, accessories, fittings and adaptors as shown on the Contractor's approved shop drawings, the Bill of Quantities and as specified herein.

The chlorination system shall be complete with 50 kg chlorine gas cylinders, chlorine gas vacuum regulators, chlorine gas manifolds, dual cylinder scale, automatic switchover systems, dashpot assemblies, valves, chlorine gas ball valves, gas chlorinators, chlorine ejectors, chlorine gas and solution valves and piping, control appurtenances, chlorine leak detection systems, emergency chlorine scrubbers, and sets of residual chlorine analyzers. All quantities shall be as per the Bill of Quantities and shall represent the P&ID of the system.

An automated dosing system with residual chlorine analyzers shall form an integral part of the works. Manual as well as automatic controls shall be provided for the dosing pumps, with start-stop control and stroke adjustment.

G.41.1 Standards and Quality Assurance

All equipment shall be manufactured in compliance with Chlorine Institute and International Fire Code requirements where applicable for chlorine gas service. Equipment shall be of best construction with components designed for long and continuous operation in a corrosive (chlorine) atmosphere. Unless otherwise specified, all equipment and components of the chlorination system shall be from a single manufacturer and as recommended by the Chlorine Institute, Inc.

Applicable references shall include the latest editions of the Chlorine Institute Pamphlets, AWWA B301 and M20, and the International Fire Code sections pertaining to toxic and hazardous gases. All products shall be new and from a reputable and experienced manufacturer with at least ten (10) years in the field unless otherwise specified. All chlorination equipment valves, vessels and similar items shall be Chlorine Institute approved and shall carry a Chlorine Institute label.

All connections, dimensional details, instrument scales, pressure ratings and similar items associated with the equipment shall be in standard metric sizes or expressed in standard metric units. The Contractor shall warrant all components to be free of defects in materials or workmanship for twelve (12) months from the date of acceptance by the Employer.

G.41.2 Schedule of Primary Equipment

The chlorination system shall be capable of safely delivering a chlorine feed rate at the maximum dose specified for pre- and post-chlorination. The primary equipment shall include, as a minimum and as detailed in the Bill of Quantities:

- Chlorine gas cylinders of 50 kg capacity, arranged as duty, standby and store quantities as scheduled;
- Dual cylinder digital scale(s), each to accommodate 50 kg cylinders;
- Vacuum regulator valve with heater and pressure relief for each duty and each standby cylinder, up to 1 kg/hour chlorine (Cl₂) capacity;
- Chlorine gas automatic switchover system;

- Horizontal gas manifolds and all related gas piping;
- Chains for fixing the duty and standby cylinders to the wall;
- Chlorine gas detector with two (2) sensors and supplemental audible and visual alarms, one for the chlorination room and one for the store room;
- Gas chlorinators, wall mounted, arranged as duty and standby, up to 5 kg/hour (Cl₂) capacity each;
- Chlorine gas ejectors, arranged as duty and standby, up to 5 kg/hour capacity each;
- Chemical injectors for pipe and open-channel injection, suitable for chlorine solution service;
- Residual chlorine analyzers with sampling points at the inlet and outlet of the works;
- All pipes, fittings, valves including safety shutoff valve, ball valves, pressure indicators and all other required accessories as indicated in the Bill of Quantities and P&IDs;
- Emergency chlorine gas scrubber, emergency repair kit, air breathing apparatus, spares and special tools for normal operation and maintenance;
- HVAC and electric heater to maintain the chlorination room within the specified temperature range;
- Booster set for the chlorine ejectors, vertical multistage type, arranged as duty and standby.

G.41.3 Chlorine Cylinder Racks and Anchorage

For pre- and post-chlorination, racks or stands suitable for 50 kg chlorine gas cylinders shall be provided, sufficient to hold the scheduled number of cylinders safely, with safety chains and locking devices. Cylinders not on scales shall be secured in racks or heavy-duty cylinder stands appropriate for chlorine gas cylinders and compliant with safety regulations (OSHA, UFC, NFPA, CGA) on a flat floor. Hinged retainer bars with hitch pin and safety chains shall provide safe cylinder containment and convenient access from each side.

Racks may be floor or wall mounted and shall be constructed from 11 gauge or heavier plate steel or hot-rolled tube steel, rugged built for durability and equipped with safety chains for holding cylinders firmly. Cylinders shall always be secured to prevent them from falling, in accordance with Chlorine Institute Pamphlet 76.

G.41.4 Weighing Scales (Dual Cylinder)

The dual cylinder weighing scale shall be designed for weighing minimum 300 mm diameter cylinders, with two independent weighing discs and digital LCD displays preferred. It shall have a gross capacity range of at least 0 to 158 kg per disc, high accuracy of $\pm 0.1\%$ of capacity, and sturdy three-point suspension on the weighing platform. The load cell shall be of the hydraulic or electrical load cell type, with an epoxy-finished frame that tilts up for easy cleaning. The electronics shall be housed in a NEMA 4X or IP66 approved enclosure.

G.41.5 Automatic Switchover System

The automatic switchover system shall be for a vacuum gas feed system and shall automatically switch chlorine feed from an empty set of 50 kg cylinders to a set of full standby cylinders, ensuring chlorine gas supply without interruption of chlorination. The design capacity and materials of construction shall be suitable for the specified service conditions and shall include an integral control panel.

G.41.6 Vacuum Regulators

Vacuum regulators shall be provided for the chlorine gas produced from the 50 kg cylinders, arranged as duty and standby including one on the weighing scale. Each regulator shall be designed to prevent pressure building in the vacuum system by means of a spring-loaded, diaphragm-actuated pressure relief valve located at the regulator, with no vent connections in the vacuum system except for the regulator vent outlets. The regulator shall provide gas shut-off capability, a captive yoke connection conforming to the Chlorine Institute, and positive indication of operating mode.

Each vacuum regulator shall be vacuum operated and fitted with a corrosion-resistant metallic safety inlet valve and a field-replaceable filter capsule with fusion-bonded epoxy coating. It shall be mounted on the cylinder and provided with a liquid trap, a vent and a dual-scale pressure gauge, with gas vent connections vented to the outside of the building. Vacuum parts shall be PVC, seals PTFE and FPM, and pressure components nickel-plated brass, ceramic or Hastelloy. PVC ball valves for vacuum service shall be true-union, true-block design with Viton O-ring seals and ISO threaded connections. Each regulator shall include a mechanism to indicate when the cylinder is empty and requires replacement.

G.41.7 Gas Chlorinators

Chlorinators shall be wall mounted and of the all-vacuum operated solution feed type for dispensing chlorine, having an automatic feed range of 10:1 and the capability to control feed rate within 4% of indicated. Chlorinators shall have flow-pacing capabilities with initial setup based on manual input. A vacuum supply gauge and ejector vacuum gauge shall be mounted on the front of the unit. The differential regulating valve shall maintain a constant vacuum across the V-notch orifice and shall be separate and independently mounted from the vacuum relief valve. Needle valves shall not be used as the feed rate control orifice.

Each gas feeder shall be provided with an integral automatic control system consisting of a dedicated electronic controller and actuator, mounted in a NEMA 4X (or IP66 with corrosion protection) enclosure and constructed of UL-94 flame-resistant materials. The actuator shall position the V-notch plug, contain a reversible motor with thermal overload protection, and provide a mechanical manual override, limit switches and feedback potentiometer. The controller shall operate in flow-proportional or manual mode via the operator keypad, with a full-text alphanumeric backlit LCD display and a six-button membrane touch keypad with tactile feedback. A dual-function high/low vacuum switch shall be mounted and pre-wired in the cabinet, and a preventive maintenance kit shall be provided.

G.41.8 Chlorine Ejectors

Chlorine ejectors shall be suitable for the capacities and pressure conditions shown in the Contractor's approved shop drawings and the Bill of Quantities, arranged as duty and standby. They shall be provided with threaded or flanged connections, manual throat adjustment, and a double check arrangement to prevent water from leaking into the chlorine gas supply when the ejector is not operating. Each ejector shall be equipped with a vacuum gauge and an auxiliary spring-loaded diaphragm, and shall be made of PVC. The Contractor shall check the back pressure of the system, supported by design notes, calculations and datasheets in accordance with the final site configuration, and shall verify that the selected motive water pumps are compatible with the selected ejectors.

G.41.9 Chlorine Gauges and Injection

Chlorine vacuum, solution and water supply pressure gauges shall be of the diaphragm-protected type, each including an indicating dial, C-type phosphor bronze Bourdon tube, stainless steel rotary geared movement, phenolic or polypropylene solid front turret case, adjustable pointer, and acrylic plastic or shatterproof glass window. The dial shall

have a white background with black markings and the units of measurement indicated on the dial face. Diaphragm seals shall be provided with Viton diaphragms, carbon steel upper housing and PVC lower housing.

Chlorine solution injection points for pipes shall be provided as per the Bill of Quantities. Each point shall consist of a chemical injection point suitable for chlorine solution, with corporation stop, inlet connection, ball valve and check valve. The material shall be PVC. Diffusers shall be supported with corrosion-resistant supports of suitable material and shall be installed for easy removal and disconnection.

G.41.10 Motive Water Pump Sets

Vertical multistage centrifugal booster pumps shall be provided with the necessary valves, instrumentation and pressure vessels, arranged as duty and standby, sized to the total flow and head scheduled. The motive water booster set flow and head shall be verified against the requirements of the selected chlorine ejectors and injection points at site.

G.41.11 Supplemental Equipment, Valves and Piping

The Contractor shall furnish and install all piping, valves, flow meters and rotameters, expansion assemblies, relief assemblies, drip legs, fittings, gaskets, bolts, nuts, couplings, anchors and supports, and all other materials required for the complete installation within the chlorine cylinder storage room and the chlorinator room. All materials in contact with chlorine shall be suitable for the service. Installation, cleaning and testing shall be as per the Chlorine Institute's recommendations. Hydrocarbons or alcohols shall not be used for cleaning; oil, grease and foreign material shall be removed using a suitable chlorinated solvent in strict compliance with the solvent manufacturer's recommendations.

Chlorine and chlorine solution pressure lines shall use seamlessly welded Schedule 80 stainless steel, Schedule 80 carbon steel (ASTM A106) or cast iron with appropriate fittings. PVC and polyethylene (PE) pipes and fittings, suitable for chlorine service and approved by the Chlorine Institute, shall be used for chlorine gas under vacuum and for chlorine solution. All flanges and unions on chlorine pressure piping shall be ammonia type. Plant water and drain piping shall be galvanized steel or PVC. Isolation valves on pressurized lines shall be ball or rising-stem type with cast iron or steel bodies, Hastelloy trim, Teflon seats and stainless steel balls, with ball valves preferred.

Upon completion of fabrication, chlorine gas and liquid piping shall be purged with nitrogen or dry air having a maximum dew point of – 40 degrees C until thoroughly cleaned and dry. After drying, the system shall be flushed with a suitable solvent to ensure all oil or grease is removed, filled with dry air or nitrogen, and tested for leaks by application of soapy water to joints. Small quantities of chlorine gas shall then be introduced, the test pressure built up to 10 bar gauge with dry air or nitrogen, and the system tested for leaks. All piping and equipment shall be thoroughly purged of chlorine before any repairs are attempted.

All uninsulated non-metallic piping such as PVC, CPVC, HDPE and PVDF shall be protected from local stress concentrations at each support point by non-metallic protection shields. Shields shall have a minimum thickness of 1.27 mm, be not less than 300 mm in length, and be securely fastened with Type 316L stainless steel straps not less than 15 mm wide. Multiple suspended horizontal plastic pipe runs shall be supported on ladder-type cable trays with rung spacing of 300 mm, and individual pipes secured to the rungs by strap clamps at spacing not exceeding 2.7 m, providing firm support while allowing longitudinal thermal movement.

G.41.12 Emergency Chlorine Scrubber

The emergency chlorine scrubber shall be designed with a chlorine neutralization capacity capable of handling the full content of the largest storage container in the facility. When a high-level leak occurs, the pump and fan shall start automatically; the fan shall provide sufficient vacuum to contain the toxic vapours within the chlorine cylinder storage

room, and the vapours shall be pulled into the scrubber where they are absorbed by a concentrated caustic solution. The system shall comprise, as a minimum, an FRP multistage scrubber, an FRP exhaust fan and a caustic recirculation pump. Only manufacturers with a minimum of ten (10) years documented experience in emergency chlorine scrubbers shall be considered.

G.41.13 Ventilation

Emergency ventilation shall be provided for the chlorine gas feed and storage rooms; in case of a leak, 60 air changes per hour shall be provided. All chlorine gas feed rooms and storage rooms shall have entirely separate mechanical ventilation systems that exhaust directly to the exterior atmosphere.

G.41.14 Safety and Emergency Equipment

One emergency repair kit for 50 kg chlorine cylinders, known as the Chlorine Institute Emergency Kit “A”, shall be provided, containing devices to stop leaks through the cylinder valves. Two (2) sets of self-contained breathing apparatus (SCBA) and two (2) sets of supplied-air respirator units shall be provided, meeting the requirements of the National Institute for Occupational Safety and Health. Each SCBA shall consist of a full- face mask assembly with wide-angle vision and anti-fogging, a 30-minute air supply tank with back-carrying harness, air flow regulator and an audible low-air alarm.

Each chlorination building shall be equipped with a safety shower complete with eye/face wash station, installed at the outside wall or immediate vicinity of the building, with a delayed-action self-closing valve connected to a potable water line. A first-aid area shall be provided with protective clothing, breathing apparatus and the necessary safety signage.

G.41.15 Chlorination Testing and Commissioning

The tests on completion of the chlorination system shall include the injection rate, injection pressure, absence of leaks, injected concentrations, compliance with specification, safety criteria, and such other tests as the Engineer may determine. All chlorine gas and liquid piping shall be leak-tested as specified above prior to commissioning, and the complete system shall be demonstrated to operate safely and automatically under the specified leak-detection and scrubber-activation sequences.

G.42. Energy Efficiency of Pumping Plant

G.42.1 Scope and Precedence

This Clause applies to every pump set supplied, installed or overhauled under the Contract, including submersible borehole pump sets, horizontal and vertical centrifugal and multistage pumps, packaged booster sets and their motors, variable frequency drives and starters.

Where a requirement of this Clause conflicts with an efficiency requirement stated elsewhere in Part G, this Clause shall govern. In particular:

- the efficiency stated in Clause G.37.8.1 for submersible borehole pumps, and the hydraulic efficiency stated in Clause G.37.13 K, are pump hydraulic efficiencies; the overall efficiency requirement of Clause G.42.3 applies in addition to them;
- in Clause G.37.13 L the words “efficiency class IE2” are deleted and the words “efficiency class IE3 to IEC 60034-30-1” are substituted;

- Clause G.40.3, Testing of Pumps, is extended by Clauses G.42.6 and G.42.7.

G.42.2 Definitions

For the purposes of this Clause:

- Pump hydraulic efficiency is the ratio of the hydraulic power delivered by the pump, $\rho g Q H$, to the mechanical power at the pump shaft, at the duty point.
- Motor efficiency is the ratio of the mechanical power at the motor shaft to the electrical power supplied to the motor terminals, at the load corresponding to the duty point.
- Drive efficiency is the ratio of the electrical power delivered to the motor to the electrical power drawn by the variable frequency drive or starter, at the operating point.
- Overall efficiency, also called the wire-to-water efficiency, is the ratio of the hydraulic power delivered by the pump to the electrical power drawn at the incoming terminals of the motor starter or drive, and is the product of the pump hydraulic efficiency, the motor efficiency and the drive efficiency.
- The duty point is the combination of flow and total head stated for the pump set in the Bills of Quantities, or as subsequently determined by the Project Manager following the hydraulic design under Clause E.6 and, for a well, the pumping test under Clause F.10.

G.42.3 Minimum Efficiencies

The following minimum efficiencies shall be achieved at the duty point, with clean cold water, and shall be guaranteed by the Contractor:

Item	Pump sets of rated output 15 kW and above	Pump sets of rated output below 15 kW
Pump hydraulic efficiency — submersible borehole pumps	$\geq 70 \%$	$\geq 65 \%$
Pump hydraulic efficiency — surface centrifugal, multistage and booster pumps	$\geq 75 \%$	$\geq 70 \%$
Motor efficiency class — dry motors	IE3 to IEC 60034-30-1, as a minimum; IE4 where a motor of that class is available for the rating and speed required	IE3 to IEC 60034-30-1, as a minimum, for motors of 0.75 kW and above
Motor efficiency — submersible wet motors	$\geq 85 \%$ at the duty point, certified by the manufacturer	$\geq 80 \%$ at the duty point, certified by the manufacturer
Variable frequency drive	Losses declared to IEC 61800-9-2; efficiency not less than 97 % at the operating point; drive of class IE2 or better	As for sets of 15 kW and above
Overall (wire-to-water) efficiency — submersible borehole pump sets	$\geq 60 \%$	$\geq 55 \%$
Overall (wire-to-water) efficiency — surface pump sets and booster sets	$\geq 70 \%$	$\geq 65 \%$

Submersible wet-rewound motors fall outside the scope of IEC 60034-30-1 and no IE class is assigned to them. For those motors the Contractor shall submit the manufacturer's certified efficiency at the duty point and shall satisfy the values stated in the table above.

Where, for a pump set of rated output below 7.5 kW, a set meeting the overall efficiency stated above is not commercially available for the duty required, the Contractor shall submit evidence of the efficiency of the best available alternatives from not fewer than three manufacturers, and shall obtain the written approval of the Project Manager before ordering. In no other case shall a lower efficiency be accepted.

G.42.4 Selection and Sizing

Pump sets shall be selected so that the duty point lies between 70 and 120 per cent of the flow at the best efficiency point of the pump, and preferably between 80 and 110 per cent. No pump shall be selected to operate continuously beyond 110 per cent of the flow at its best efficiency point, nor below 50 per cent of it.

The Contractor shall not add a margin to the scheduled duty head or flow beyond that stated in the Bills of Quantities. Where the Contractor considers that a margin is required, it shall declare it, state its magnitude and its justification, and obtain the approval of the Engineer. Oversizing, whether of the pump or of the motor, which results in the set operating away from its best efficiency point, shall be a ground for rejection.

The head-flow characteristic of every pump shall be continuously rising towards shut-off, without a region of instability, and this shall be demonstrated by the certified curve. Where pumps operate in parallel, the characteristics shall be such that the duty is shared within 10 per cent.

The available net positive suction head at the maximum flow and the minimum water level shall exceed the net positive suction head required by the pump by not less than 1.0 m, or by 30 per cent of the required value, whichever is the greater.

Where the duty varies, variable speed operation shall be provided. The minimum permitted speed shall be set so that the pump does not operate below 50 per cent of the flow at its best efficiency point, and, for a submersible pump, so that the velocity of water past the motor remains above the minimum required for cooling. The limits shall be set in the drive and recorded in the operation and maintenance manual.

G.42.5 Submissions before Ordering

The Contractor shall submit the following for the approval of the Engineer not less than 28 days before placing an order for any pump set. No pump set shall be ordered before the submission has been approved.

- Certified performance curves from the manufacturer for the actual impeller diameter and stage count offered, showing head, power absorbed, efficiency and required net positive suction head against flow, over the full operating range, with the duty point and the best efficiency point marked, to ISO 9906:2012 acceptance grade 2B, or grade 1B for sets of rated output 55 kW and above.
- The motor efficiency certificate, stating the efficiency class to IEC 60034-30-1 and the efficiency at 100, 75 and 50 per cent of rated load determined in accordance with IEC 60034-2-1; or, for a submersible wet motor, the manufacturer's certified efficiency at the duty point and at 75 per cent of it.
- The loss and efficiency data for the variable frequency drive, declared in accordance with IEC 61800-9-2, at the operating points relevant to the duty.
- The system head curve for the installation, derived from the hydraulic design submitted under Clause E.6 and, for a well, from the pumping test under Clause F.10, with the duty point shown at the intersection with the pump characteristic.
- The completed Schedule of Guaranteed Pump Performance, Form G.42-1.
- The calculation of the specific energy consumption at the duty point, in kilowatt-hours per cubic metre delivered.

G.42.6 Testing at the Manufacturer's Works

Every pump shall be performance tested at the manufacturer's works in accordance with ISO 9906:2012, to acceptance grade 2B, or to grade 1B for sets of rated output 55 kW and above, and in accordance with Clause G.40. The test shall

establish head, power absorbed and efficiency at not fewer than five points covering the operating range, including shut-off and the duty point.

Where practicable the pump shall be tested with the motor and the drive offered for the Works, so that the overall efficiency is established directly. Where this is not practicable, the overall efficiency shall be computed from the tested pump efficiency and the certified motor and drive efficiencies, and the computation shall be submitted with the test certificate.

Tests on pump sets of rated output 30 kW and above shall be witnessed by the Engineer, unless the Engineer waives attendance in writing, in which case certified test records shall be submitted. The Contractor shall give not less than 21 days' notice of a works test.

Acceptance shall be judged against the guaranteed values in Form G.42-1, within the tolerances of the acceptance grade applied. Where a pump fails to achieve the guaranteed efficiency, the Contractor shall modify or replace it at its own cost and shall repeat the test; no pump that has failed shall be delivered to Site.

G.42.7 Testing on Site and Acceptance

After installation, and before the Works or any Section of them are taken over, each pump set shall be tested on Site in the presence of the Engineer. The test shall establish, at the duty point and over not less than 30 minutes of steady running, with readings taken at the start, at the mid-point and at the end:

- the flow, measured by the installed flow meter, the calibration of which shall have been verified;
- the total head, computed from calibrated pressure gauges on the suction and delivery sides, corrected for the difference in datum and for velocity head; for a submersible borehole pump, from the delivery pressure at the well head and the dynamic water level measured through the dip tube;
- the electrical power drawn at the incoming terminals of the starter or drive, measured with a power analyser of class 1 or better, calibrated within the preceding twelve months;
- the voltage and the current in each phase, the power factor, and, where a drive is installed, the operating frequency.

The overall efficiency shall be computed from these measurements and compared with the guaranteed value. An allowance of three percentage points shall be made for the uncertainty of site measurement.

Where the measured overall efficiency, after that allowance, is below the guaranteed value, the Contractor shall investigate the cause, shall rectify it at its own cost and shall repeat the test. Where the guaranteed value cannot be achieved, the Project Manager may instruct the replacement of the plant, or may accept it and value the shortfall in accordance with the Contract.

The results of every site test shall be recorded on a form approved by the Engineer, signed by the Contractor and by the Engineer, and included in the operation and maintenance manual and, for a well, in the well file required by Clause F.13.

G.42.8 Energy Metering and Records

Every pumping installation shall be provided with a kilowatt-hour meter on the incoming supply to the pumping plant, or, where a variable frequency drive with an integral energy counter is installed, with that counter configured to record cumulative energy; and with a flow meter complying with Clause G.33.21 on the delivery.

At commissioning the Contractor shall record the specific energy consumption of each installation in kilowatt-hours per cubic metre delivered, measured over not less than 24 hours of normal operation, and shall enter it in the operation and

maintenance manual as the datum against which the South Lebanon Water Establishment will monitor the performance of the plant in service.

The operation and maintenance manual shall state, for each pump set, the duty point, the best efficiency point, the minimum and maximum permitted operating flows, the guaranteed and the measured overall efficiency, the specific energy consumption at commissioning, and the action to be taken if the specific energy consumption rises by more than 15 per cent above that value.

G.42.9 Form G.42-1 — Schedule of Guaranteed Pump Performance

The following Schedule shall be completed by the Bidder for every pump set offered, and shall be submitted with the Bid and again, as finally offered, with the submission required by Clause G.42.5.

Particular	Pump set 1	Pump set 2	Pump set 3	Pump set 4	Unit
Tag number and location					—
Type of pump					—
Manufacturer, model and stage count					—
Duty flow					m ³ /h
Duty total head					m
Flow at best efficiency point					m ³ /h
Duty flow as a percentage of best efficiency point flow					%
Pump hydraulic efficiency at duty					%
Net positive suction head required at duty					m
Motor rated output					kW
Motor efficiency class					—
Motor efficiency at duty					%
Drive efficiency at duty					%
Guaranteed overall (wire-to-water) efficiency at duty					%
Specific energy consumption at duty					kWh/m ³
Acceptance grade of works test offered					—

Technical Specifications

Electrical Works

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H.1. GENERAL PROVISIONS FOR ELECTRICAL WORK

H.1.1 General

H.1.1.1 Description

All electrical work shown on the inferable therefrom.

H.1.1.2 Quality Assurance

General provisions contained in this Section, shall apply and form a part of each and every section of specification.

The Contractor shall verify that the materials, appliances, equipment or devices he furnishes and installs under this Contract, meet the requirements of the Local LEBANON Standards, as regards fire and casualty hazards. The Contractor shall submit independent proof for review by the Client that the materials, appliances or devices conform to established standards, including methods of test, of the country of origin.

In addition to the requirements shown or specified in the Contract Documents, all equipment shall be manufactured, tested and installed in accordance with the latest editions of the following standards:

- IEC - International Electrotechnical Commission
- DIN - Deutsch Industrial Normen
- IEEE - Institute of Electrical and Electronic Engineers
- IES - Illuminating Engineering Society
- VDE - Verband Electrotechniker
- EDL - Electricity Company of LEBANON
- ISO - International Standardization Organization
- ETA/TIA - Electronic Industries Association / Telecommunication Industries Association
- CISPR - International Special Committee on Radio Interference
- Ministry of Industry and Electricity.
- Ministry of Communications.
- LEBANON Standards Organization.
- ASHREA / IESNA: American Society of Heating Refrigeration and Airconditioning Engineers 90.1 – 99.
- IECC: International Energy Conservation code , Code , 2000.

All items of labour and material required to comply with such standards and codes in accordance with the requirements of the Contract Documents shall be included..

The layout of equipment, accessories, specialties, wireways and conduit systems are diagrammatic unless specifically shown and/or dimensioned. They do not necessarily indicate every required fitting, elbow, transition, junction box, pull box or similar item required for a complete installation. Except for areas of particular importance from the design stand-point, branch circuit and associated wire and conduit routing are not shown adjacent to equipment. The Contractor shall provide required branch circuit conduit and wire as required to serve equipment with the circuits assigned on the Contractor's approved shop drawings. Where branch circuit information and routing are shown, conduit and wiring for same shall be installed accordingly.

The general arrangement of conduit, wiring and equipment shall be shown on the Contractor's approved shop drawings. Detailed drawings and proposed departures due to actual field conditions or other causes shall be submitted to the Client for review. The Contractor shall carefully examine all drawings and shall be responsible for the proper fitting of materials and equipment in each location as indicated, without substantial alterations. The Contractor shall carefully investigate the structural and finish conditions affecting his work and shall arrange such work accordingly, furnishing such fittings and accessories as may be required to meet such conditions.

Contractor shall refer to specification for any additional requirements.

H.1.1.3 Submittals

Shop Drawings: The Contractor shall submit for review by the Client, detailed dimensioned shop drawings as stipulated in the other sections of specification Electrical. These drawings shall be prepared by the Contractor, shall be based on manufacturers installation instructions and shall not be reproductions or tracings of the design drawings. In preparing shop drawings, lines and levels for the work specified shall be established and the drawings shall be checked thoroughly to avoid interference with structural features and the work of other trades.

Shop drawings shall show all equipment, wireways and conduit to be installed. Shop drawings and/or data sheets shall be based on information stated in the specifications and and shown on the Contractor's approved shop drawings and shall show all pertinent information and data for the fabrication and complete installation.

Manufacturer's literature: Manufacturer's data sheets shall be submitted indicating the necessary installation dimensions, weights, materials and performance information. The performance shall include complete electrical data, including power conditions and identifying types and numbers. Where pertinent, electrical diagrams shall be provided. The above information may be provided by standard sales catalogue sheets marked to indicate the specific equipment provided.

Operation and Maintenance Instructions: The Contractor shall furnish data covering model, type and serial numbers, capacities, maintenance and operation of each item of equipment or apparatus in accordance with the requirements of the Contract Documents. Operating instructions shall cover all phases of control. And also shall provide all additional requirements from materials, spare parts tools, equipment in accordance with General Requirements Sections.

H.1.1.4 Electrical Utilities

The substation shall accommodate the consumers medium voltage equipment 5.5 kV,

3 PH, 50 Hz., transformers to step this voltage down to 400 / 230 V, 3 PH, 50 Hz., TNC.S system.

Unless otherwise noted, the following voltage levels shall be utilized:

- The incoming to all buildings will be 400 / 230 V, 3 PH, 50 HZ.,
- HVAC large equipment will be powered at 400 V, 50 HZ.
- Lighting : 230 V.
- Convenience outlets : 230 V and 400V
- Motors : 230 V, 1 PH for motors $\leq$ 1 HP 400 V, 3 PH for motors $>$ 1 HP

H.1.1.5 Product Handling

The Contractor shall be responsible for keeping stocks of material and equipment stored on the premises in a neat and orderly manner.

The exposed surfaces of wireways, conduit systems or equipment which have become covered with dirt, plaster or other material during handling and construction shall be thoroughly cleaned by the Contractor, before such surfaces are prepared for final finish, painting, or enclosed within the building structure.

The Contractor shall clean and maintain the work in accordance with the Contract stipulations.

H.1.1.6 Protection

The Contractor shall keep all raceways and conduit system openings closed by means of plugs or caps to prevent the entrance of foreign matter and cover all fixtures, equipment and apparatus as required to protect them against dirt, moisture, water, chemical or mechanical damage both before and after installation.

Plugs and caps shall be of such types as to prevent transmission of flood water through any duct, conduit or raceway. Any fixtures, equipment or apparatus damaged prior to initial acceptance of the work shall be restored to its original condition or replaced by the Contractor. At completion, fixtures and equipment shall be thoroughly cleaned.

The Contractor shall be held responsible for all damage done until initial acceptance. Any material or equipment that is damaged in transit, damaged during installation or damaged as a result of any phase of construction, will not be accepted, and should be replaced at no cost to the Client.

H.1.1.7 Coordination

The Contractor shall be held responsible for the proper coordination of all phases of the work under this Contract.

It shall be the responsibility of the Contractor to coordinate the work and equipment as specified herein with work to be performed and equipment to be furnished, under other sections of the specifications in order to assure a complete and satisfactory installation.

H.1.1.8 Quality of Equipment

Quality shall be of the best grade for each type or class, even though such quality may not be stated specifically in the specifications. All materials and products shall be new and manufactured by well known firms and shall be sound and uniform in quality, size, shape, color and texture and shall be free from cracks, warpage, or other defects.

H.1.1.9 Temporary Power

The Contractor shall furnish and install all temporary electrical facilities, including lamps, required for construction and safety operations. All such equipment shall remain the property of the Contractor and shall be removed when permanent connections have been completed. Where it is determined, during construction, that the temporary facilities, as installed, interfere with other construction operations, the Contractor shall relocate said facilities in an approved manner. No wire, bus or electrical equipment which is part of any of the permanent electrical systems may be used for temporary electrical service for construction operations. Temporary connections shall be safe and in accordance with accepted practices. The Contractor shall be responsible for any damage or injury to equipment, materials, or personnel caused by improperly protected temporary installations. All costs for materials and installation for temporary electrical facilities and energy for their operation shall be at the expense of the Contractor.

Electric welders used in the erection and fabrication shall be provided with an independent grounding cable connected directly to the structure on which the weld is being made rather than to adjacent conduit, piping, etc.

H.1.1.10 Manufacturers' Nameplates

Each major component of the equipment shall have the manufacturer's name, address, model number and rating on a plate securely affixed in a conspicuous place. The nameplate of the distributing agent will not be acceptable.

H.1.2 Products

H.1.2.1 General

All goods and products covered by these specifications shall be submitted for Engineer's prior approval to confirm the compliance of these goods and products with the requirements set in these Specifications including, but without any limitation, the general requirements..

H.1.3 Execution

H.1.3.1 Workmanship

Materials, products and equipment furnished by the Contractor, shall be installed and all work shall be performed in a first-class workmanship manner, in conformity with the best trade practices and the printed directions of the applicable manufacturers; by skilled workers equipped to produce satisfactory results; in a safe, substantial manner so as to avoid undue stresses, rigid enough to prevent undue movement, so as to present a neat, orderly appearance and to facilitate operating, servicing, maintenance and repairing. The engineer reserves the right to reject any part of the installation not complying with the specifications, and the contractor shall carry out the necessary remedial work or replacement free of charge without delaying the contract.

H.1.3.2 Excavation and Backfilling

General: Excavation and backfilling of trenches required for the installation of all Electrical Services and underground wireways and conduit systems shall be performed as shown and noted on drawings and as specified.

Trenching: Excavate to the required depths and grade, the bottom of trenches to secure the required slope for conduit and/or duct as hereinafter specified. Rock or existing concrete, where encountered, shall be excavated to a minimum depth of 150mm below the bottom of conduit, duct or concrete envelope, if so encased. Where mud or otherwise unstable soil is encountered in the bottom of the trench which is incapable of supporting the conduit, duct or concrete envelope such soil shall be removed to firm bearing and the trench shall be backfilled with sand to the proper grade and tamped to provide firm, uniform support.

H.1.3.3 Foundations and Supports

The Contractor shall provide concrete pedestals, bases pads, curbs, anchor blocks, anchor bolts, slab inserts, hangers, channels, cradles, saddles, etc., for installation of equipment and apparatus shown on the Contractor's approved shop drawings and specified in the various sections.

Concrete pads shall be 150 mm high, unless otherwise indicated, complete with steel reinforcing and necessary bolts, anchors, etc. Where concrete pad is set directly on concrete floor, dowels in floor to tie base to floor shall be provided. These pads shall be extended at least 100 mm beyond the equipment outline on all four sides.

Individual hangers, trapeze hangers and riser clamps shall be provided for supporting conduit and all parts and hardware shall be hot dip galvanized cast iron malleable straps or structural steel with hot dip galvanized bolts and nuts.

Pipe straps and hanger rods shall be fastened to concrete by means of inserts or expansion bolts, to brickwork by means of expansion bolts and to hollow masonry by means of toggle bolts. Wooden plugs and shields shall not be used for fastening pipe strips and hangers.

Under no circumstances shall ductwork, piping and mechanical equipment be used for supporting electrical facilities.

H.1.3.4 Sleeves, Chases and Openings

Pipe sleeves for electrical conduit passing through walls shall be of sufficient length to extend through the full thickness of the construction, with ends flush with the finish on each side, unless noted otherwise.

The Contractor shall provide necessary chases and openings in the walls, partitions and floors to accommodate his work.

Chases, sleeves and openings in fire rated walls and floors (telephone, electrical closets, etc.) shall be packed with acceptable mineral wool insulation or approved flexible barriers designed for the purpose shall be used.

Whenever any of the work of the electrical system has to pierce any water proofing, this work shall be done with care and after the part of the system has been put in place through this waterproofing, the opening made by same shall be waterproofed and made absolutely watertight.

H.1.3.5 Cutting and Patching

The Contractor shall provide chases, holes and openings for installation purposes and carefully fit around, repair, patch and otherwise make his work acceptable.

He shall furnish and install all sleeves and inserts required for this work. Cutting and patching of any part of the structure shall be done only after review by the Client.

H.1.3.6 Painting

All shop fabricated and factory built equipment not galvanized, plated or provided with a standard finish paint, shall be cleaned and given one shop coat of a lead free primer paint, before delivery to the site. Any portions of the shop coat damaged in delivery or during construction shall be recoated. Under no circumstances, shall be nameplate, label or tag of any equipment be covered with field painting.

H.1.3.7 Tests

Prior to starting the electrical installation, the Contractor shall verify the correct voltage, phases and current consumption of all utilization equipment to be connected.

The Contractor shall provide any materials, equipment and labor required and make such tests as specified in the various sections and as deemed necessary to show proper execution of the work.

Any defects or deficiencies discovered as a result of such tests shall be corrected without additional cost to the Client.

After the installation is complete and properly adjusted, the Contractor shall conduct operating tests. The various equipment and systems shall be demonstrated to operate in accordance with the requirements of the Contract Documents. Tests shall be performed in the presence of the Client. The Contractor shall provide electric power, instruments and personnel necessary for performing the various tests.

H.1.3.8 Equipment Erection

General: All electrical equipment shall be erected or installed in accordance with the manufacturer's recommendations, good electrical engineering practice, and the relevant drawings and specifications.

Location Tolerances: Equipment shall be located within 3mm of the dimensional location on the Contractor's approved shop drawings, unless otherwise permitted by the Client.

Bolted Electrical Connections: All metal surfaces to be bolted shall be thoroughly cleaned before assembly. The connections shall be tightened with manual torque wrenches to the manufacturer's erection instructions.

The tightened bolts shall be tested at random in the presence of the Client.

Lubrication: The Contractor shall furnish all oils, greases, and other lubricants in accordance with the manufacturer's recommendations, to the Client's approval.

H.1.3.9 Equipment Testing and Commissioning

General: The testing of all electrical equipment shall include, but not be limited to, the items below. This shall be in addition to testing specified in Article 3.07 or elsewhere in this specification.

- General equipment check.
- Field wiring and ground system verification
- Conductor insulation tests
- Equipment adjustment
- The testing shall be a continuous process to maintain the construction schedule to the satisfaction of the Client.

Grounding: All grounding materials and labour are part of electrical works. Testing and grounding of manholes and cable, shall include, but not be limited to the tests below:

- Earth continuity tests shall be made from each item of equipment to the appropriate main ground system, and on the main ground system to the ground rods.
- The resistance to ground for selected ground rods: All ground resistance measurements shall be made with a three terminal "megger" type ground tester which applies alternating current to the electrodes and which gives a reading in direct current ohms. Two reference ground probes shall be used and all tests shall be made in accordance with the instrument manufacturer's instructions for ground resistance testing.

Prior to connection of ground rods to the grounding system the Contractor shall obtain individual measured ground resistance data from selected ground rods to be indicated on the Contractor's approved shop drawings. These data shall be obtained, identified, and recorded under the supervision of the Client and the results sent to the Client within five days.

After connection of ground rods to each manhole's grounding mat, the Contractor shall obtain a ground resistance measurement from a flush ground plate. These data shall be obtained, identified, and recorded and the results sent to the Client within five days.

The ground resistance measurement data may indicate that additional ground rods are required. The Contractor shall furnish, install, and connect additional ground rods as the Client may direct.

H.2. ELECTRICAL CONNECTIONS FOR EQUIPMENT

H.2.1 General

H.2.1.1 Description

General:

- Furnish all labour, materials, tools, equipment, and services for all wiring of equipment to be indicated on the Contractor's approved shop drawings and in accord with provisions of Contract Documents. Completely coordinate with work of all other trades.
- Although such work is not specifically indicated, furnish and install all supplementary or miscellaneous items, appurtenances and devices incidental to or necessary for a sound, secure and complete installation.

Related work specified elsewhere:

- General Requirements.
- General Provisions For Electrical Work.
- Mechanical.
- Electrical.
- Equipment.

Provide all conduit, wiring, outlet boxes, receptacles, circuit breakers, fittings, switches, starters, (with overloads) etc., to make final connections to all equipment.

H.2.1.2 Submittals

Shop drawings: Required for Client's review.

Product data: Required for Client's review.

Contract close-out information: Required for Client's review.

Product samples to be provided for Client's review and all approved samples to be considered as Client properties.

H.2.2 Products

H.2.2.1 Heating, Cooling and Ventilating System Equipment

Provide all conduit, wire, and connect all units of heating, cooling, and ventilating equipment.

Provide all motor starters except in package or prewired units as required by the Mechanical Equipment.

- Connect all motors.
- Provide starters with thermal overload protection for all motors not having such protection, except as otherwise indicated.
- Starters, motor protectors, breakers, etc.

Provide proper thermal overload heater elements in all starters.

H.2.2.2 Pantry Equipment Beverage

Where equipment items are to be connected using plug and receptacle, provide receptacle compatible with plug.

Where equipment is to be directly connected, use flexible conduit.

Pantry electrical equipment shall be protected by breakers having 230V shunt trip, unless otherwise indicated.

H.2.2.3 Electric Signs

Provide all conduit, wiring, outlet boxes, etc., to make final connections to all exterior electric signs. Sign(s) shall be controlled by exterior lighting master controls.

H.2.2.4 Equipment

Provide all conduit, wiring, outlet boxes, receptacles, circuit breakers, fittings, switches, etc., to make final connections to all equipment.

Where equipment items are to be connected using plug and receptacle, provide receptacle compatible with plug.

Where equipment is to be directly connected, use flexible conduit .

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H.2.2.5 Fittings

Provide all conduit, wiring, outlet boxes, etc., to make final connection to all fittings.

H.2.3 Execution

H.2.3.1 Installation

Wire equipment complete properly connected and energized.

Provide conduit and wiring as required for directly connected switches as indicated or required.

H.3. EARTHING SYSTEM

H.3.1 General

H.3.1.1 General

Description of Work

- Complete installations to earth every source of energy and to provide protective earthing and equipotential bonding, based on the TN-S system arrangement as defined in IEC60304, including:
- Main earthing terminals or bars
- Exposed conductive parts of electrical equipment
- Extraneous conductive parts

Regulations and Standards

Carry out work in accordance with the following:

- IEC publications 364-3 and 364-4-41 Electrical Installations in Buildings
- Latest edition of IEE Regulations for Electrical Installations in Buildings - London.

Definitions of Terms:

To be Used on the Contractor's shop drawings and in the Specification are as follows:

- Earth Conductive mass of the Earth whose electric potential at any point is conventionally taken as zero.
- Earth Electrode Conductor or group of conductors in initial contact with, and providing electrical connection to, Earth.
- Exposed Conductive Part Any part which can be readily touched and which is not a live part, but which may become live under fault conditions.
- Extraneous Conductive Part Any conductive part not forming part of the electrical installation such as structural metalwork of a building, metallic gas pipes, water pipes heating tubes etc. and non-electrical apparatus electrically connected to them i.e. radiators, cooking ranges, metal sinks etc. and non-insulating floors and walls.
- Protective Conductor Conductor used for some measure of protection against electric shock and intended for connecting together any of the following parts:
 1. Exposed conductive parts
 2. Extraneous conductive parts
 3. Earth electrode(s)
 4. Main earthing terminal or bar(s)
 5. Earthed point of the source(s)

Protective conductor shall be equal to phase conductor for all phase conductors up to and including 16 mm. sq. Protective conductor shall be equal to half size (or next standard to half size) phase conductor, for phase conductor equal or larger than 25 mm. sq.

- Electrically Independent Earth Electrodes

Earth electrodes located at such distance from one another that maximum current likely to flow through one of them does not significantly affect the potential of the other(s).

- Main Earthing Terminal or Bar The terminal or bar provided for the connection of protective conductors, including equipotential bonding and functional earthing conductors if any to the means of earthing.
- Equipotential Bonding Electrical connection to put exposed and extraneous conductive parts at a substantially equal potential.
- Earthing Conductor Protective conductor connecting main earthing terminal or bar of an installation to earth electrode or to other means of earthing.
- Equipment Data Prior to ordering materials, submit data for approval including, but not limited to, manufacturer's catalogues for earth rods, connecting clamps, earthing conductors, protective conductors, bonding conductors, connectors and other accessories, exothermic welding kits and tools etc., and samples of conductors as requested.
- Shop and Construction Drawings Submit drawings for approval including, but not limited to, the following:
 1. Exact location of earth pits, rods and details of installation and connections.
 2. Exact routing of buried earthing conductors with indication of cross-section, depth of laying and covering.
 3. Cross sectional area of all earthing, protective and bonding conductors.
 4. Layout and details of earthing provisions at substations, generator rooms, swit, distribution panelboards etc., indicating fittings used, insulation, plates and marking, passage and routing of earthing conductors, conduit, sleeves, grooves, niches etc., giving sizes and dimensions of component parts.

H.3.2 Products and System

H.3.2.1 Earthing System (Type TN-S)

General Requirements: Earthing system shall comply with the general requirements of these Specifications.

Component Parts of earthing system are to include the following:

- Earth electrode (rods, tapes etc.)
- Main earthing terminals or bars
- Earthing conductors
- Protective conductors
- Equipotential bonding conductors
- Accessories and termination fittings, bonding, welding kits and other materials.

Earth Electrodes is to consist of one or more earth rods, interconnected by buried earthing tape or cable, installed under finish of ground floor, as an interconnection through buried grounding grid at 60cm below ground grack is not feasible due to waterproofing problem. Earth electrode shall have a total combined resistance value, during any season of the year and before interconnection to other earthed systems or earthing means, not exceeding 5 ohms. Distance between two rods is not to be less than the length of one rod, or 3 m minimum.

Functional Earth Electrode is to be provided separately from, but interconnected to, other earth electrode(s) through suitably rated (470 V) spark gap. Functional earth electrodes are to be used for earthing electronic equipment

(communication equipment, digital processors, computers etc.) as required, recommended by the manufacturer and approved by the Engineer.

Alternative Earth Electrode other types of earth electrode may be used, after approval, including:

- Cast iron pipes with special surround material
- Copper plate(s)
- Tape mats (strips)

Earth Fault Loop Impedance for final circuits supplying socket outlets, earth fault impedance at every receptacle is to be such that disconnection of protective device on overcurrent occurs within 0.4 seconds, and for final circuits supplying only fixed equipment, earth fault loop impedance at every point of utilization is to be such that disconnection occurs within 5 seconds. Use appropriate tables and present same for approval by the Engineer (IEE Regulations: Tables 41A1 and 41A2, Appendix 7 and regulation 543).

Supplementary Equipotential Bonding all extraneous conductive parts of the building such as metallic water pipes, drain pipes, other service pipes and ducting, metallic conduit and raceways, cable trays and cable Armour are to be connected to nearest earthing terminals by equipotential bonding conductors. Cross-section of protective bonding conductor is not to be less than half that of the protective conductor connected to respective earthing terminal, and minimum 4 mm².

Main Equipotential Bonding main incoming and outgoing water pipes and any other metallic service pipes are to be connected by main equipotential bonding conductors to main earth terminal or bar. Bonding connections are to be as short as practicable between point of entry/exit of services and main earthing bar. Where meters are installed, bonding is to be made on the premises side of the meter. Cross-sections of conductors are not to be less than half that of the earthing conductor connected thereto, and minimum 6 mm².

Identification connection of every earthing conductor to earthing electrode and every bonding conductor to extraneous conducting parts is to be labeled in accordance with the Regulations, as follows:

"SAFETY ELECTRICAL CONNECTION - DO NOT REMOVE".

Identification protective and earthing conductors are to be identified by combination of green-and-yellow colors of insulation or by painting bar conductors with these colors, as approved.

Identification source earthing conductor (or neutral earthing conductor) is to be identified along its entire length by continuous black insulation labeled, 'neutral earthing'.

H.3.2.2 Transformer Substation Earthing

Transformer substation earthing shall be implemented by LOCAL ELECTRICAL AUTHORITY- description hereunder is provided as a guideline for coordination between LOCAL ELECTRICAL AUTHORITY and Contractor in order to apply Codes requirements.

MV SWITCHGEAR is to have separate main earthing bar connected to framework or earth bar of each item by bare conductor and the earth-electrode by two insulated earthing conductors, one at each end of bar, via testing joints. Earthing conductor is to be minimum 50 mm².

LV SWITCHGEAR is to have separate main earthing bar connected to framework or earth bar of each item by bare conductor and the earth electrode at two extreme ends by two insulated earthing conductors through testing joints. Earthing conductor size is to be minimum 120 mm².

TRANSFORMER EARTHING TERMINAL is to be connected to LV main earthing bar by bare copper earthing conductor not less than 20 mm² per 100 KVA of transformer rating, with a minimum of 35 mm².

TRANSFORMER NEUTRAL (STAR POINT) is to be connected by insulated earthing conductor (colour black) to LV side main earthing bar. Neutral earthing conductor is to be sized for maximum earth fault current for 5 seconds with final conductor temperature not exceeding 160 deg. C or sized not less than 30 mm² per 100 KVA of transformer rating, and with a minimum of 50 mm². Where a neutral is directly connected to earth electrode, an insulated disconnecting device is to be provided at the transformer.

LIGHTNING ARRESTERS are to be directly connected to earth electrode, following the shortest path. Each lightning arrester is to be connected at a dedicated earth rod.

H.3.2.3 Earthing of Main Distribution Boards, Panelboards,

LIGHTING INSTALLATIONS AND WIRING ACCESSORIES

MAIN EARTHING BAR is to be provided in main distribution room and connected to earth electrode by two insulated conductors (minimum 120 mm²) via testing joints.

EARTHING BARS OF MAIN DISTRIBUTION BOARDS are to be connected, by bare earthing conductor, directly to main earthing bar at main distribution room and by protective conductor run with incoming feeder from respective supply point.

DISTRIBUTION, LIGHTING AND POWER PANELBOARDS are to be connected by protective conductors run together with incoming feeder cable, connecting earth terminals in panelboards with respective main distribution board earthing bar.

SOCKET OUTLETS are to be earthed by protective conductor looped around with the branch circuit and connected to earth terminal within socket outlet box and to which socket outlet terminal is to be connected.

FINAL RING SUBCIRCUITS : protective conductor of every final ring sub-circuit is to be in the form of a ring having both ends connected to earth terminal at origin of circuit in panelboard.

LIGHTING FIXTURES AND OTHER EXPOSED CONDUCTIVE PARTS of electrical installations, such as switches, heaters, air conditioning units etc. are to be connected by protective earth conductors to earthing terminals of respective panelboards.

H.3.2.4 Generator Plant Earthing

GENERATOR NEUTRAL (STAR POINT) is to be connected by insulated earthing conductor through the neutral earthing link or device to main earthing bar. Neutral earthing conductor is to be suitably sized to carry maximum earth fault current for time it takes the system protection to operate with final conductor temperature not exceeding 160 deg. C, but not less than 30 mm² per 100 KVA of generator rating, with a minimum of 50 mm².

GENERATOR EARTHING TERMINAL is to be connected to main earthing bar by bare copper conductor of cross section not less than 20 mm² per 100 KVA of generator size, with a minimum of 35 mm².

SWITCHGEAR (ATS) AND CONTROL GEAR : earthing terminals or bars of switchgear and control gear are to be connected by separate protective conductors to respective normal and emergency main distribution board earth bars.

EXTRANEIOUS CONDUCTIVE PARTS including steel frames, battery racks, day-tank, pumps and piping are to be connected by bare copper earthing conductors to main earth bar in compliance with bonding regulations.

H.3.2.5 Mechanical Plant Rooms and Fixed Machinery

MAIN EARTHING BAR OR LOOP is to be conveniently located in mechanical plant rooms, and connected by earthing conductors to exposed conductive parts of motor control center at its earthing bar, and to motors, switches and other

electrical equipment etc. at their earthing terminals, using 20 x 2 mm bare copper strips or 35 mm² bare copper conductor (minimum size) or as required to carry maximum earth fault current for 1 second with final conductor temperature not exceeding 200 deg. C. Conductors are to be securely fixed, recessed in floor grooves or niches, or fixed to walls by appropriate staples. Earth bar or loop is to be securely fixed to building wall with copper or brass saddles.

MAIN EARTHING BAR OR LOOP is to be connected at two extremely separate points to earth electrode, directly through two test joints by insulated earthing conductors, or connected to main earth bar by protective conductors.

MOTOR AND OTHER EQUIPMENT EARTH TERMINALS are to be connected also by protective earth conductors of each branch circuit to earth terminal/bar at motor control center, panel or distribution unit.

H.3.2.6 Materials and Products

EARTH ROD: copper steel, 14 mm diameter, 2.5 m length, extendible as necessary to obtain required earth resistance. Earth rod is to be complete with couplings, head and bolted connector of sufficient size, and number of bolted clamps to cancel cables terminated thereto.

BURIED EARTH CONDUCTORS: bare annealed copper strip conductors 25 x 2.5 mm, or annealed stranded copper conductors 70 mm 2 cross-section.

TAPE MATS : where earth rods are not likely to be used, earth electrode is to consist of parallel and perpendicular copper strip, 2.4 m apart, welded together by exothermic welds to form a grid. Tape is to be 25 x 2.5 mm strip conductor.

EARTH PIT: precast, square or circular section concrete handhole (minimum 450 mm internal diameter), with concrete cover, and extending to about 150 mm below top of earth rod. Earth pit is to be provided for each earth rod where connected to an earthing conductor. Cover is to have inset brass plate with inscription 'Earth Pit - Do Not Remove'.

EARTHING CONDUCTORS: insulated or bare copper conductor as required, recommended by the manufacturer, and approved by the Engineer.

TESTING JOINTS (TEST LINKS): copper or copper alloy, with bolted end connections, disconnectable by use of tool, and suitably sized for earthing conductors or earth bar connection. Links are to be fixed to porcelain or other approved insulating supports. Contact surfaces are to be tinned.

PROTECTIVE CONDUCTORS: single core stranded annealed copper, PVC insulated cables, having rated insulation grade compatible with circuit protected, or to be a conductor forming part of a multi-core cable, colour coded.

MAIN EARTHING BAR: hard drawn copper, 40 x 4 mm where formed into a closed loop, and 50 x 6 mm where open-ended. Earth bar is to be labeled 'Main Earth Bar' and is to be drilled, for connection of conductors, at a spacing not less than 75 mm, and is to be supplied with copper alloy bolts, nuts and washers and wall mounting insulators.

PROTECTIVE BONDING CONDUCTORS: bare copper strip conductors, annealed stranded copper cable or flexible strap (flexible braid) of cross-sectional area as required in these specifications and recommended by manufacturer for Engineer's approval.

EARTHING ACCESSORIES: copper or copper alloy, purpose made, of approved design, compatible with points of connection, and of adequate cross-section and current carrying capacity. Connectors and clamps are to be bolted type. Bolts, nuts and washers are to be high quality phosphor bronze or copper silicon alloys.

H.3.3 Execution

H.3.3.1 Field and Installation Work (Installation)

Continuity: ensure that complete earthing system is electrically continuous and mechanically secure.

Earth Rods: while siting earth rods, ensure that resistance areas associated with individual rods do not overlap. Earth rods are to be located at a distance greater than 600 mm from foundations of buildings. Where rock is encountered, a hole of sufficient size is to be drilled before lowering the rod. Conductive filler such as Marconite or Bentonite or equal filler that will not corrode is to be provided around the rod.

Buried Earthing Conductors are to be laid at a depth not less than 0.8 m from

Earthing Conductors: are to follow shortest path between earth rods and main earthing terminals or bars, and are to run in PVC conduit (duct) fastened to building structure by approved supports and extending 0.2 m above level, and are to be protected against mechanical damage and corrosion.

Protective Conductors: separate protective conductors, which are not part of a cable, are to be fixed on same support or drawn into same conduit as circuit conductors.

Protective Bonding: remove any non-conductive paint, enamel or similar coating at threads, contact points and surfaces and ensure that bonding is made by fittings designed to make secure bonds.

Protection Against Corrosion: protect bolted connections against corrosion either by filling with Vaseline or coating with a special anti-corrosion compound and proper capping.

Connections: earth connections are to be readily accessible. If inaccessible earth connection is permitted, approved exothermic welding or brazing technique is to be employed.

Connections: where earth connections between dissimilar metals must be made, use bimetallic fittings and protect by coating with moisture resisting bituminous paint or compound, or by wrapping with protective tape to exclude moisture.

H.3.3.2 Tests on Site and Records

Combined Resistance of earth electrodes is to be measured during dry season and checked against specified resistance.

Electrical Continuity of all earthing and protective conductors including main and supplementary equipotential bonding conductors is to be checked.

Earth Fault Loop Impedance of all circuits is to be measured and checked against calculated impedance figures.

Records: submit the following:

- Scaled drawings, as-installed, showing actual layout and specification of all components of earthing system.
- Nature of soil and any special earth arrangements etc.
- Date and particulars of soil conditioning method and agents if used.
- Test conditions and results obtained.

OPERATING AND MAINTENANCE MANUALS are to contain the following:

- Technical description of each system and item of equipment installed, written to ensure that the Employer's staff fully understand the scope and facilities provided
- Diagrammatic drawings of each system indicating principle components and items of equipment

- Schedules (system by system) of equipment installed giving manufacturer, catalogue list numbers, model, rating, capacity and operating characteristics; each item is to have a unique code and number, cross- referenced to the diagrammatic drawings and layout drawings
- Name, address, telephone, telex and fax numbers of the manufacturer of every item of equipment
- Name, address, telephone and telex numbers of equipment agents/representatives for emergency services and procedures
- Manufacturer's service manual for each major item of equipment, assembled specifically for the project, including detailed drawings, illustrations, circuit details, operating and maintenance instructions, modes of operation, control provisions, sequences and interlocks and preventative maintenance programme
- Schedules of all fixed and variable equipment settings established during commissioning
- Procedures for fault finding, where applicable
- Manufacturers' lists of recommended spare parts for items subject to wear and deterioration, giving expected running period and indicating specifically those items which may involve extended deliveries.

OPERATING AND MAINTENANCE MANUALS : prepare two temporary copies with provisional record drawings and preliminary performance data and make available at time of testing and commencement of commissioning to enable the Employer's staff to familiarize themselves with the installations. Temporary copies are to be in the same format as the final manuals with temporary insertions for items, which cannot be finalized until installations are commissioned, and performance tested.

H.3.3.3 Training

OPERATION AND MAINTENANCE TRAINING: before the date of substantial completion, explain and demonstrate to the Employer's maintenance staff the purpose, function and operation of the installations including all items and procedures listed in the operating and maintenance manuals. Include for not less than thirty days for this purpose.

H.4. HANGERS AND SUPPORTS FOR ELECTRICAL SYSTEMS

H.4.1 General

H.4.1.1 Related Documents

Drawings and general provisions of the Contract, including General and Supplementary Conditions and Specification Sections, apply to this Section.

H.4.1.2 Summary

This Section includes the following:

- Hangers and supports for electrical equipment and systems.
- Construction requirements for concrete bases.

H.4.1.3 Definitions

- EMT: Electrical metallic tubing.
- IMC: Intermediate metal conduit.

- RMC: Rigid metal conduit.

H.4.1.4 Performance Requirements

Delegated Design: Design supports for multiple raceways, including comprehensive engineering analysis by a qualified professional engineer, using performance requirements and design criteria indicated.

Design supports for multiple raceways capable of supporting combined weight of supported systems and its contents.

Design equipment supports capable of supporting combined operating weight of supported equipment and connected systems and components.

Rated Strength: Adequate in tension, shear, and pullout force to resist maximum loads calculated or imposed for this Project, with a minimum structural safety factor of five times the applied force.

H.4.1.5 Submittals

Product Data: For the following:

- Steel slotted support systems."
- Nonmetallic slotted support systems.

Shop Drawings: Show fabrication and installation details and include calculations for the following:

- Trapeze hangers. Include Product Data for components.
- Steel slotted channel systems. Include Product Data for components.
- Nonmetallic slotted channel systems. Include Product Data for components.
- Equipment supports.

Welding certificates.

H.4.1.6 Coordination

Coordinate size and location of concrete bases. Cast anchor-bolt inserts into bases.

Concrete, reinforcement, and formwork requirements.

Coordinate installation of roof curbs, equipment supports, and roof penetrations.

H.4.2 Products

Conduit and Cable Support Devices: Steel hangers, clamps, and associated fittings, designed for types and sizes of raceway or cable to be supported.

Support for Conductors in Vertical Conduit: Factory-fabricated assembly consisting of threaded body and insulating wedging plug or plugs for non-armored electrical conductors or cables in riser conduits. Plugs shall have number, size, and shape of conductor gripping pieces as required to suit individual conductors or cables supported. Body shall be malleable iron.

Structural Steel for Fabricated Supports and Restraints: ASTM A 36/A 36M, steel plates, shapes, and bars; black and galvanized.

Mounting, Anchoring, and Attachment Components: Items for fastening electrical items or their supports to building surfaces include the following:

- Powder-Actuated Fasteners: Threaded-steel stud, for use in hardened Portland cement concrete, steel, or wood, with tension, shear, and pullout capacities appropriate for supported loads and building materials where used.
- Concrete Inserts: Steel or malleable-iron, slotted support system units similar to MSS Type 18; complying with MFMA-4 or MSS SP-58.
- Clamps for Attachment to Steel Structural Elements: MSS SP-58, type suitable for attached structural element.
- Through Bolts: Structural type, hex head, and high strength. Comply with ASTM A 325.
- Toggle Bolts: All-steel springhead type.
- Hanger Rods: Threaded steel.

H.4.2.1 Fabricated Metal Equipment Support Assemblies

Description: Welded or bolted, structural steel shapes, shop or field fabricated to fit dimensions of supported equipment.

Materials: Comply with requirements in Section "Metal Fabrications" for steel shapes and plates.

H.4.3 Execution

H.4.3.1 Application

Maximum Support Spacing and Minimum Hanger Rod Size for Raceway: Space supports for conduits EMT, IMC, and RMC as required by NFPA 70. Minimum rod size shall be 1/4 inch (6 mm) in diameter.

Multiple Raceways or Cables: Install trapeze-type supports fabricated with steel slotted or other support system, sized so capacity can be increased by at least 25 percent in future without exceeding specified design load limits.

1. Secure raceways and cables to these supports with two-bolt conduit clamps.

Spring-steel clamps designed for supporting single conduits without bolts may be used for 1-1/2-inch (38-mm) and smaller raceways serving branch circuits and communication systems above suspended ceilings and for fastening raceways to trapeze supports.

H.4.3.2 Support Installation

Raceway Support Methods may be supported by openings through structure members, as permitted in NFPA 70.

Strength of Support Assemblies: Where not indicated, select sizes of components so strength will be adequate to carry present and future static loads within specified loading limits. Minimum static design load used for strength determination shall be weight of supported components plus 200 lb (90 kg).

Mounting and Anchorage of Surface-Mounted Equipment and Components: Anchor and fasten electrical items and their supports to building structural elements by the following methods unless otherwise indicated by code:

- To Wood: Fasten with lag screws or through bolts.
- To New Concrete: Bolt to concrete inserts.
- To Masonry: Approved toggle-type bolts on hollow masonry units and expansion anchor fasteners on solid masonry units.
- To Existing Concrete: Expansion anchor fasteners.
- Instead of expansion anchors, powder-actuated driven threaded studs provided with lock washers and nuts may be used in existing standard-weight concrete 4 inches (100 mm) thick or greater. Do not use for anchorage to lightweight-aggregate concrete or for slabs less than 4 inches (100 mm) thick.

- To Steel: Spring tension clamps
- To Light Steel: Sheet metal screws.
- Items Mounted on Hollow Walls and Nonstructural Building Surfaces: Mount cabinets, panel boards, disconnect switches, control enclosures, pull and junction boxes, transformers, and other devices on slotted-channel racks attached to substrate.

Drill holes for expansion anchors in concrete at locations and to depths that avoid reinforcing bars.

H.4.3.3 Installation of Fabricated Metal Supports

Cut, fit, and place miscellaneous metal supports accurately in location, alignment, and elevation to support and anchor electrical materials and equipment.

Field Welding: Comply with AWS D1.1/D1.1M.

H.4.3.4 Concrete Bases

Construct concrete bases of dimensions indicated but not less than 4 inches (100 mm) larger in both directions than supported unit, and so anchors will be a minimum of 10 bolt diameters from edge of the base,

Use 3000-psi 28-day compressive-strength concrete. Concrete materials, reinforcement, and placement requirements.

Anchor equipment to concrete base.

- Place and secure anchorage devices. Use supported equipment manufacturer's setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
- Install anchor bolts to elevations required for proper attachment to supported equipment.
- Install anchor bolts according to anchor-bolt manufacturer's written instructions;

H.4.3.5 Painting

Touchup: Clean field welds and abraded areas of shop paint. Paint exposed areas immediately after erecting hangers and supports. Use same materials as used for shop painting.

1. Apply paint by brush or spray to provide minimum dry film thickness of 0.05 mm.

Touchup: Comply with requirements in "painting Sections" for cleaning and touchup painting of field welds, bolted connections, and abraded areas of shop paint on miscellaneous metal.

Galvanized Surfaces: Clean welds, bolted connections, and abraded areas and apply galvanizing-repair paint to comply with ASTM A 780.

H.5. BASIC MATERIALS AND METHODS

H.5.1 General

H.5.1.1 Description

Furnish, install and test conduits, raceways, ducts, cable trays, boxes, wires and cables, connectors, insulating tape and resin, switches, receptacles for power, communication and control systems.

Related work specified elsewhere:

- General Provisions for Electrical Work

- General requirements.

H.5.1.2 Applicable Codes and Standards

The following codes and standards are intended to provide an acceptable level of quality for materials and products:

- LIBNOR – Lebanese Standards Institution
- IEC – International Electro technical Commission. D. ISO – International Standardization Organization.
- Latest Edition of IEE Regulation for Electrical Installation in Buildings.
- CCITT – International Telephone and Telegraph Consultation Committee.
- ASHREA / IESNA: American Society of Heating Refrigeration and Airconditioning Engineers 90.1 – 99.
- IECC: International Energy Conservation code, Code, 2000.

H.5.1.3 Submittals

- Shop Drawings and Manufacturer's Literature.
- List of Manufacturers
- Wire and Cable
- Conduits and Fittings
- Overcurrent Devices

H.5.2 Products

H.5.2.1 General

All goods and products covered by these specifications shall be approved by the Client and conforming with the requirements of specifications. Procurement of all goods and products must be approved by the Client.

H.5.2.2 600 Volt Wire and Cable

Refer to Section Wire and Cable.

H.5.2.3 Connectors, Insulating Tape and Resin

Connectors, Terminal Lugs and Fittings:

For 6mm² and smaller conductor cable: Pressure type tin plated copper connectors having non-flammable and self-extinguishing insulation with temperature rating equal to that of the conductor insulation.

For 10mm² to 120mm² conductor cable: Compression type tin plated copper connectors and terminal lugs having conductor insulation grip.

For 150mm² and larger conductor cable: Long barrel double compression type tin plated copper connectors and terminal lugs with two hole pad.

Binding Straps: Self-locking steel barb on one end, with tapered strap on self-extinguishing nylon of minus 54°C to 121°C temperature rating.

For outdoor use: Ultraviolet resistant nylon strap with the above characteristics. Insulating Tape:

Plastic tape: Vinyl plastic tape with rubber-based pressure-sensitive adhesive, pliable at a low temperatures.

Thickness 0.5 microns Breaking strength 3.5 kgs/cm (width) Elongation 200 percent Dielectric breakdown 10,000 volts Insulation resistance 1,000,000 megohms Rubber tape:

Silicon rubber tape with silicon pressure-sensitive adhesive and having following minimum properties:

Thickness 0.38 mm

Breaking strength 2.3 kgs/cm (width) Elongation 525 percent Dielectric breakdown 13,000 volts Insulation resistance 1,000,000 megohm Epoxy Resin:

Suitable for insulating and moisture sealing cable splices and having the following minimum properties:

Dielectric strength 15,800 volts per mm

Volume resistance 2.8×10^{15} ohm per centimeter cube at 30°C.

Water absorption 0.193 percent in 24 hrs. at 23°C 0.62 percent in 24 hrs. at 53°C

Tensile strength 5.624 tons per square metre

Elongation 2.4 percent

H.5.2.4 Conduits and Fittings

Galvanized rigid steel conduits: Rigid steel conduits and fittings shall be in accordance with IEC-364 Part-5. Conduits shall have an interior and exterior zinc coating of uniform quality and appearance throughout all surfaces. They shall consist of steel tubes with threaded fittings, couplings and connecting devices. Rigid conduits and fittings shall be manufactured specially for electric wiring purposes. When manufactured by a continuous weld process, weld heads both inside and outside the tube will be completely removed prior to galvanizing.

Plastic coated conduit shall be epoxy, PVC or phenolic coated.

Electrical Metallic Tubing (EMT): Electrical metallic tubing shall be steel, zinc-coated on the inside and out-side. The maximum size of EMT shall be 100 mm.

Polyvinyl Chloride (PVC) conduit and fittings: Shall be rigid heavy gauge with high impact and high temperature resistance, flame retardant with the following properties:

Flame rating Self-extinguishing Tensile strength 41.3 Mpa at 26°C Compressive strength 58.6 Mpa

Thermal conductivity 670 watt per meter degree celsius

Liquid-Tight Flexible Conduit: Shall be consisting of flexible galvanized steel core with continuous copper bonding conductor spiral wound between convolutions, extruded liquid tight neoprene jacket overall.

Conduit Expansion Couplings: Fabricated from material similar to that of conduit with which coupling is to be used, having factory installed packing ring and pressure ring to prevent entrance of moisture. Metallic couplings equipped with grounding ring or grounding conductor.

Conduit Connector Fittings: Shall be material similar to that of conduit with which they are to be used, with the following additional requirements.

For enclosures, cabinets, boxes and gutters in dry locations: Nylon insulated housing and locknut.

For enclosure, cabinets, boxes and gutters in outdoor or indoor locations subject to moisture or dirt: Tapped conduit hub.

For enclosure having punched or formed knockout for conduit entry: Watertight hub fitting with gasket, nylon insulated throat and locknut.

Conduit Seal Fittings: Capable of providing electrical insulation and watertight seal between concrete and the conduit penetrating wall, floor or ceiling and of type as shown.

Conduit and Cable Supports:

Shall be of type, style and size: As required.

Material and finish: Steel or galvanized malleable iron, hot dip galvanized after fabrication.

For separating conduit from masonry surface: Galvanized malleable iron spacer assembled with style A strap.

For vertical run of metallic sheath cable: Basket weave type cable support. For fastening conduit or cable to channel inserts: Galvanized steel fasteners.

Multiple pipe hangers (trapeze type): Consisting of two or more hanger rods, horizontal member, U-bolt clamp and other attachment necessary for securing hanger rods and conduit, with the following additional requirements:

Material and finish: Steel hot dip galvanized after fabrication.

Hanger rod: Not smaller than 10mm (3/8 inch) diameter, threaded for sufficient distance each end to permit at least 38mm (1.5 inch) of adjustment.

Horizontal member: 38mm by 38mm or 40mm x 40mm channel 12 gauge or heavier. Two or more channels welded together for greater strength if necessary.

H.5.2.5 Outlet and Junction Boxes

Outlet Boxes: Capable of accommodating the conduits, mentioned in the last paragraph, with the following additional requirements:

Material and finish: Steel, malleable iron, or ductile iron dip galvanized after fabrication.

For outdoor or indoor locations subject to moisture or dirt: Outlet boxes with threaded conduit entrance hub.

For wall receptacles and switches:

Outlet boxes two devices European or American standard as approved by the Client.

For receptacles and switches mounted on glaze tiles, concrete blocks, marble, stone or wood, except for floor receptacles: Outlet boxes European or American standard as approved by the Client.

For floor receptacles: Watertight cast iron outlet boxes, 100mm diameter, of suitable depth and complete with the following:

Adjustment screws for final leveling.

Bronze floor plate with flush mounted screw plug, without exposed fastener, medium satin finish.

Screw plug attached to outlet box assembled by chain or other means.

Bronze floor plate flange, 127mm diameter, extending beyond the box 13mm over the top of finished floor.

One special screw plug removal tool with every 10 boxes. Junction and pull boxes:

Internal volume up to 1.60, internal volume above 1.60 with the following requirements:

Flush or surface mounting type as shown.

Size: Suitable to accommodate the conduit, raceways, ducts, number of cables and splices as shown.

Material and finish: Steel, malleable iron, or ductile iron hot dip galvanized after fabrication.

H.5.2.6 Cabinets

Shall be fabricated from galvanized steel, surface mounted unless otherwise shown, tamperproof, with a backplate of reinforced steel for mounting interior components, for rigid support and accurate alignment.

Provision for cabinet grounding.

Four (4) flat keys tumbler cylinder type nickel plated door lock conforming to station master key system, 4 keys per lock.

Finish: Metallic surface thoroughly cleaned, degreased, primed with zinc primer and then finished with gray paint after fabrication.

H.5.2.7 Cable Trays

Shall generally be ladder type, galvanized steel, with the following additional requirements:

Dimensions: 76mm inside depth and 228 mm rung spacing unless otherwise shown.

Load rating: 74.4 kgs/metre with a safety factor of two. Bend radius: 610mm unless otherwise shown.

Hot dipped galvanized cable trays of perforated type shall be acceptable. All such cable trays shall be heavy duty type.

All bends, elbows, fittings and accessories shall be from the manufacturer same as of cable trays. Samples shall be submitted for Client's review and approval.

H.5.2.8 Lighting Switches

Lighting switches shall be modular snap type (flush tumbler-toggle), heavy duty general use type, single pole, double pole, 2-way or intermediate to be indicated on the Contractor's approved shop drawings, with the following requirements:

Rating: 20 amperes at 230 volts, 50 HZ.

Body and base: Fully enclosed type, fire-resistant non-absorptive thermosetting phenolic compound or approved equal.

Contacts: Silver alloy.

Mounting yoke: Corrosion resistant metal with plaster ears.

Switches shall be of fashionable design with overlapping cover plate flush mounted and back and wired with terminals of screw or combination screw-clamp type and shall be provided with fixing plates to fit on Standard boxes. Wiring terminals shall be capable of receiving and holding 4mm² wire size. The switches will be supplied complete with support, mechanism and overlapping cover plates. The mechanism shall be clip-on type directly into support frame.

H.5.2.9 Socket Outlets and Plugs

Receptacles and plugs shall be heavy duty general use type to conform with standard European practice, with the following requirements, to be indicated on the Contractor's shop drawings:

Plugs: 16 amperes 230 volts to be shown on the Contractor's shop drawings..

Base and body: Fire-resistant non-absorptive thermosetting phenolic compound or equal, compatible with type of socket outlet specified, of impact resistant moulded insulating material and of shape providing easy hand-grip for removal.

Outlet: Single or duplex as shown.

Mounting Yoke: Corrosion resistant metal with plaster ears. Rating:

Two pole, three wire 16 amps 230 volts. Plugs:

Rating:

Two pole, three wire, 16 amps, 230 volts

Armored cap with cord grip

Weather proof socket outlets shall be min. IP44 with cover. All socket outlets shall be

1 P+E + N.

Outlets shall be of flush mounted unless otherwise indicated on the Contractor's approved shop drawings. Wall outlets shall be single or duplex as shown on the Contractor's approved shop drawings and mounted in single-gang spacing. Outlets shall be rigidly attached to outlet boxes by means of screws. Outlets will be provided with fixing plates to fit them on standards boxes. For exterior locations, outlets shall be mounted in watertight, flush cast type outlet boxes with threaded hubs and equipped with gasketed covers and captive caps of the screw or twist type. The outlets will be supplied complete with support, mechanism and cover plate. The mechanism shall be clip-on type directly into support frame.

Power socket outlet – Type R 45 (400 V service), 3 phase, polarized, earthing type, rated 32 A, to IEC 309, with splash proof cast metal box and hinged spring – returned plate, and with matching plug.

H.5.2.10 Cover Plates

Wall plates shall be of attractive design, with the following additional requirements:

For use in Architecturally important Areas: Color as required by the Client

For non-public areas: Stainless steel Tampico brushed.

H.5.2.11 Caulking Compound

Compound for the sealing of conduits, ducts, pipes and sleeves shall be of a putty-like consistency workable with the hands at temperatures as low as 1.7°C shall not slump at a temperature of 149°C and shall not harden materially when exposed to air.

H.5.3 Execution

H.5.3.1 Method of Wiring, General

Complete metal raceways or enclosures shall be provided for conductors throughout all systems specified. Equipment and devices which are not constructed with housings for mounting and enclosing all live parts, shall be installed in metal cabinets. All equipment, enclosures, raceways, etc., shall be appropriate for the atmosphere and hazards encountered within their associated areas.

In public areas and in normally occupied and/or finished rooms and spaces all conduits, cables, cable trays and wire gutters, etc., shall be concealed and out of sight.

Wiring for power and communication systems shall consist of insulated conductors installed in raceways and conduits. The following conduits shall be used:

Galvanized rigid steel conduit for exposed installations, where EMT is not allowed and where larger than 100 mm conduits are required. In mechanical and electrical rooms for exposed installation galvanized rigid steel conduits shall be used.

Electrical Metallic Tubing (EMT), galvanized, 100 mm and smaller for exposed wiring above 1200 mm from floor except where subject to mechanical damage and for concealed wiring in walls or ceilings. All fittings shall be watertight type.

Flexible metallic conduit, where required because of equipment vibration such as motor connections, at expansion joints for exposed wiring. Provide approved fittings in damp and wet locations.

Polyvinyl chloride (PVC) conduit, heavy wall schedule 40 or equivalent for wiring embedded in concrete slab and for underground installations encased in a concrete envelope.

H.5.3.2 Conduit Installation

General: Conduit and conduit systems shall be provided as specified in this Section and to be indicated on the Contractor's shop drawings:

Conduit shall be provided in standard 3 m lengths.

Size of conduit for all applications shall not be smaller than 20 mm except where noted otherwise.

All interior conduit buried in concrete or fill shall be PVC unless otherwise shown and shall utilize fittings rated both "concrete tight" and watertight.

All conduits in connection with ceiling outlets for exposed concrete ceilings shall be embedded in the slab. Where outlets occur in concrete finished ceilings, walls or columns, outlet boxes shall be installed flush with the finished surface.

All conduit installed in wet locations or subject to mechanical injury shall be rigid steel. All conduit and tubing bends or offsets shall be made by means of an approved bending

device and so formed that there will be no cross sectional distortion of the conduit.

Conduit fittings, long radius prefabricated threaded elbows or bends may be used with metal conduit, but normal water or gas pipe elbows, fittings, welded connections or gas pipe elbows, fittings, welded connections or slip joint fittings will not be permitted. The radius of all bends will be at least 6 times the internal diameter of the conduit or tubing for rubber conductors.

Conduit shall generally be concealed. Conduit shall be exposed only as shown and/or noted on the Contractor's shop drawings and as specified. All exposed conduits shall run parallel with building walls using right angle bends. Exposed diagonal runs of conduit will not be permitted unless specifically noted otherwise.

In mechanical equipment spaces, ceiling outlets and conduit shall be exposed avoiding ventilating ducts and mechanical piping. Where numerous ducts occur, conduits and outlets shall be installed after the ventilating ducts. All exposed conduit runs shall be rigidly suited to the conditions under which they are used.

Conduit shall be installed at least 300 mm from steam or hot water piping in parallel runs, at least 150 mm in cross-runs and at least 75 mm from cold water piping.

If conduit runs from point to point exceed 45m in length or exceed total of 3-90° bends, provide pull boxes in locations, accessible at all times.

Where conduit runs occur in spaces having furred down ceilings, conduits shall be installed above the furred ceiling and not in the floor slab or fill unless specifically noted otherwise.

Vertical runs in cores and closets shall be supported at every floor; support intervals must not exceed 4m.

Couplings and Connections: Couplings, connectors and fittings shall be of a type specifically designed and manufactured for the purpose. The Contractor shall supply all necessary hangers, straps, couplings unions, fittings or other material to install and support the conduit, tubing and boxes in a permanent and rigid manner on the type of surface provided, consistent with the architectural treatment in the location.

Drainage: Conduit shall be installed so as to provide drainage. It shall be incumbent upon the Contractor to exercise the necessary precautions to install conduits as far as it is possible to prevent the accumulation of water. All conduits shall be thoroughly cleaned and swabbed out before any wires or cables are drawn in.

Underground Conduit: Conduit running through un-excavated areas or under floor slabs lying directly on earth fill shall be encased in 75mm concrete envelope. Each underground joint shall be sealed and made watertight with white lead. Conduit shall be sealed and made watertight with white lead. Conduit shall be galvanized rigid steel or galvanized with overall PVC coating.

Flexible Conduit: Where final connection to equipment with rigid conduit is not practicable, such as to equipment with adjustable mountings, at transformers to eliminate transmission of vibration, etc., flexible conduit shall be used.

Provide expansion fittings where conduit or tubing crosses expansion joints.

All conduits shall be secured to outlet boxes, junction boxes or cabinets by placing locknuts on outside of box and locknuts and bushings on the inside of box.

Conduit to motors shall terminate in the conduit fittings on the motors, the final connection being made with liquid tight flexible conduit and suitable "liquid-tight" connectors.

Fish Wire: A 2 mm galvanized iron fish wire shall be left in every rigid conduit or metallic tubing which is left by the Contractor for installation of wires or cables.

H.5.3.3 Wire and Cable Installation

General: The Contractor shall provide a complete system of new wire and cable comprised of copper conductors as specified herein and to be shown on the Contractor's shop drawings:

Branch circuit wires for lighting shall not be smaller than 4mm². Control wiring shall not be smaller than 1.5mm² unless otherwise shown on the Contractor's shop drawings. Branch wires for socket outlets shall not be smaller than 4mm².

Fixture Wiring shall be stranded, rated 600 volts and shall be suitable for 150°C, operating temperature, of type appropriate for dry or wet locations unless noted specifically otherwise.

Wire Pulling Lubricants: Powdered soap stone or other commercially produced wire lubricant may be utilized to ease wire pulling; however, any such lubricant shall be of a type to produce no deteriorating effect on conductor installation or on the interior of associated wireway.

H.5.3.4 Cable Trays

- **General:** Each run of cable tray is to be completed before installation of cables. Submit calculations taking into consideration the maximum load on cable trays with a factor of safety of two (min.).
- **Supports and barriers:** Provide supports to prevent stress on cables entering or leaving tray. Cable trays extending through partitions and walls are to be protected by fire proof, non- combustible barriers.
- **Trays:** Remove sharp edges, burrs and projections and finish trays smooth. Fix trays using approved suspension rods or steel angle brackets at spacing not exceeding 1.5 m and generally as shown on the Contractor's shop drawings. Minimum clearance of 250 mm is to be maintained between top of tray and ceiling, beams and other services and between trays in multi – tier formation.

- Cables: Secure to trays with purpose made straps or saddles and arrange in one layer only, evenly spaced, or as shown on the Contractor's shop drawings, with minimum spacing of one diameter of the larger of the two adjacent cables or of a trefoil formation of single core cable circuit.
- Earthing: Do not use metal trays as earth continuity conductor. Connect trays by flexible tinned copper straps to nearest bare earthing conductor and at maximum 30 m spacing.
- Connections to equipment: Where cable trays connect to equipment, provide tray flanged fittings fastened to the tray and to the equipment. Support the tray separately. Do not carry the weight of the tray on the equipment enclosure.
- Barriers: Where trays carry conductors of different systems, such as power, communications and data processing, or different insulation levels, such as low and medium tension cables use separate cable trays. In case of absolute necessity, install insulating barriers to separate the systems after obtaining the engineer's approval.

H.5.3.5 Cable Trunks (Wiring Gutters)

Cable trunks shall be installed in accessible spaces only. Where cable trunking passes over building expansion joints, the side of a coupling section shall be arranged to take- up building movement and an earth continuity conductor comprising a loop of copper braiding shall be bolted to each side of the joint.

H.5.3.6 Conduit Accessories

Each item of fixed electrical equipment shall be provided with conduit box to suit condition and of proper size to contain conductors, splices, wiring devices, sockets and equipment support studs as required.

Where for reasons of construction, conduit box face is not flush with wall or ceiling finish, purpose made extension rings shall be provided of same construction and diameter as conduit box.

Floor Boxes: For individual mounting in concrete floors, verify exact location of floor outlet boxes. Securely fasten box to concrete form, provide temporary box cover during pour, adjust top of box to exact height of finished floor. Provide flush floor mounted convenience outlets in floor boxes where shown; Provide floor plates and nipples suitable for mounting of power, telephone and data outlets. Where floors are carpeted provide suitable carpetings.

H.5.3.7 Taps, Splices and Terminations

Make wire and cable splices in outlet, junction, pull boxes or equipment cabinets. Splices in conduit, raceways, or trench ducts are not permitted.

Secure connectors or terminal lugs to the conductor to engage all strands equally. Do not rupture insulation nor expose bare conductors.

Install compression type connectors and terminal lugs using tools and pressure recommended by the manufacturer. Indent mark connectors and terminal lugs with number of die used for installation.

Apply anti-corrosion joint compound to connectors, terminal lugs and bolting pads before installation.

For conductors 4mm² and smaller use solderless connectors of twist-on type as specified here in before.

For taps in conductors 6mm² and larger use bolt type connectors as specified. Bolt type connectors shall be provided with insulation covers or each connector shall be taped with adequate layers to provide same insulation value as conductor insulation.

H.5.3.8 Cable Lugs

Shall be of type as specified here in before. Conductor insulation shall be peeled off to proper length to allow maximum of conductor length to be located in lug shaft without excessive clearance to insulation. Use hydraulic tool with proper die size to assure maximum conductivity from conductor to lug.

H.5.3.9 Wiring Devices

Wiring devices shall be of recess type installed in wall or floor boxes wherever conduits are concealed in public areas and in finished and/or normally occupied rooms and spaces. No surface devices shall be installed without written approval. Surface mounted devices shall only be installed in technical spaces, attic spaces, riser columns, service corridors, maintenance rooms, shops and similar unfinished rooms.

Wiring devices shall be mounted at heights as indicated unless otherwise noted.

Boxes for recessed devices shall be manufactured of heavy gauge galvanized sheet steel minimum 1.0 mm thick. Where more than one switch is located in same area use multigang boxes. Where more than one phase enters multigang box provide integral barriers separating switch units connected to each phase and separate covers shall be installed over such areas. Recessed device boxes shall be mounted so that cover plates fit perfectly against wall finish on all sides; avoid excessive tensions in and possible breakage of plates.

Surface mounted devices shall be installed in cast iron boxes. Provide gasketed boxes with threaded cable hubs in damp locations and where mounted exposed to weather.

H.5.3.10 Tests

Prior to starting the electrical installation, the Contractor shall verify the correct voltage, phases and current consumption of all utilization equipment to be connected.

The Contractor shall provide any materials, equipment and labor required and make such tests as specified in this section of the specifications and as deemed necessary to show proper execution of the work.

H.5.3.11 600 Volt Cable Tests

After finishing the installation of all direct burial cables, the Contractor shall test the insulation resistance of all feeders, branch circuits and connected equipment with a 600 volt Megger, for grounds and short circuits. Testing of power cables, includes measuring of insulation resistances between phase conductors and between phase and ground. These measurements shall be recorded by feeder and branch circuit number indicating the resistance values between phases and between phases and ground.

Insulation resistance is to be carried out in accordance with IEE regulations 613-5 through 601-8 and 703-04.

H.6. WIRE AND CABLE - 600 VOLT AND BELOW

H.6.1 General

H.6.1.1 Description

General:

- Furnish all labour, materials, tools, equipment, and services for wire and cable -600 volt and below as indicated on the Contractor's shop drawings and in accord with provisions of Contract Documents.
- Completely coordinate with work of all other trades.

- Although such work is not specifically indicated, furnish and install all supplementary or miscellaneous items, appurtenances and devices incidental to or necessary for a sound, secure and complete installation.
- See Section Basic Materials and Methods.

Related work specified elsewhere:

- General Provisions For Electrical Works.
- General Requirements

H.6.1.2 Submittals

Shop drawings: Required for Client's review.

Product data: Required for Client's review including, but not limited to the following:

- Constructional details, standards to which cables comply, current carrying capacities, derating factors for grouping, temperature,... etc.
- Manufacturer's catalogue cuts, dimensional and electrical characteristics samples of each cable and wire and if requested by the Engineer, other accessories.

H.6.1.3 Applicable Codes and Standards

The following codes and standards are intended to provide an acceptable level of quality for materials and products.

- LIBNOR – Lebanese Standards Institution
- IEEE - Institute of Electrical and Electronic Engineers
- IEC - International Electrotechnical Commission
- IPCEA - Insulation Power Cable Engineers Association.
- ASHREA / IESNA: American Society of Heating Refrigeration and Airconditioning Engineers 90.1 – 99.
- IECC: International Energy Conservation code , Code , 2000.

H.6.1.4 Testing

All cables shall be tested at the factory in accordance with the latest standards as specified herein. Following completion of the tests, four certified copies of the test reports shall be submitted to the Client not later than 10 days after completion of all factory tests. Impulse tests on cables and their accessories shall be as per IEC 230.

H.6.2 Products

H.6.2.1 General

All goods and products covered by these specifications shall be approved by the Client and conforming with the requirements of specifications. Procurement of all goods and products must be approved by the Client. All goods and products shall be designed for operation at sea level, an ambient temperature of 500 C and humidity of 100%.

H.6.2.2 Cables and Conductors

- General L.V. cables shall be 600/1000 volt XLPE/PVC (copper) in compliance with the standards and of cross sectional areas as detailed on drawings. The cables installed as direct buried shall be XPLE/SWA/PVC. The cables installed in conduits shall be unarmoured XLPE/PVC. Phases shall be color coded in conformity with the standards. The over-all cable sheath shall be black unless specifically detailed otherwise.

The cables shall be as per IEC 228 and 502. Unless otherwise specified, single conductor cables (building wires) for wiring in conduit are to have annealed copper conductors, compacted, generally with concentric strands and insulated with flame retardant, moisture and heat resistant to IEC 227, suitable for wet locations and for conductor temperature of 70 °C. Wires and cables are to be 450 / 750 V grade.

Multi-core PVC insulated cables (0.6 / 1 kV) to have annealed copper conductors, compacted, insulated with PVC to IEC 227, flame retardant, moisture and heat resistant, suitable for wet locations and conductor temperature of 70 °C, laid up, bedded with suitable filler and sheathed with PVC. Armoured cables, where required, are to have galvanized steel tape armour with PVC over sheath – cables to comply with IEC – 502 & 540.

Single – core XLPE insulated feeder cables (0.6 / 1 kV), single core circular stranded, annealed copper conductors, compacted, insulated with flame retardant, moisture and heat resistant cross – linked polyethylene, suitable for wet locations and conductor temperatures of 90 °C and PVC over-sheath. Armoured cables, where required, are to have taped bedding, single wire aluminum armour and PVC over-sheath.

Multi – core XLPE insulated feeder cables (0.6 / 1 kV), to have annealed copper conductors, compacted, XLPE insulated, for conductor temperature of 90 °C, laid up and bedded with suitable non-hygroscopic material compatible with the insulation and PVC over-sheathed, colour black. Armoured cables, where required, are to have double layer of galvanized steel tape applied helically over extruded PVC bedding (which may be an integral part of filling) and over-sheathed with PVC, colour black – PVC over-sheathes are to be type ST2 to IEC 502.

Flexible cable: for connection to appliances, window fans, pendants, etc. is to be 300/500 V grade, three or four core, with tinned finely stranded copper wires, EPR insulated, twisted and sheathed with chlorosulphonated polyethylene (CSP) compound and with strengthening cord.

High temperature cable – Type MICC: 1000 V grade, annealed solid copper conductors, embedded in densely compacted mineral insulant, and contained in seamless annealed tubular copper sheath for continuous operation at 250 °C and for short duration at temperatures up to 1000 °C, and water proof. Cable to be Pyrotenax or other approved equal, supplied with standard fittings, terminations, etc.

Another type is FP200, solid or stranded plain annealed copper conductors to BS 6360 (in sizes up to 4 mm²), extruded silicon rubber insulation to BS 6889 (0.6 mm radial thickness), aluminum / PVC laminate and PVC composite sheath with tinned earth continuity conductors / drain wire. Cable is rated 300 / 500 V, capable of accepting voltage surges up to 5 kV, to operate continuously at 150 °C and for short durations at 200 °C. It is to be certified to have passed IEC 331 and 332, flame resistance and fire retardant tests. Cable to be Pirelli, type FP200 or other approved equal.

Control and signal cables: 0.6 / 1 kV rating, solid 1.5 & 2.5 mm² or stranded 4 mm² plain circular copper conductors, with heat resistive to IEC 227, rated for 85 °C. Cores are to be laid up together and filled with non-hygroscopic material, PVC over-sheathed, to form compact and circular cable for use of power and lighting systems. Armoured cable, where required, is to have extruded PVC bedding which may be an integral part of the filling, galvanized steel wire armouring, and over-sheath of PVC Type ST 2 to IEC 502, colour black. Core identification is to be white printed numbers over black insulation.

H.6.2.3 Color Coding

The color coding shall be carried out for all conductors in accordance with IEC 173 and IASO standards or otherwise identified as required by the regulations. Colour coding shall be maintained throughout the entire installation.

400 Volts, 3 phase, 4-wires system: Phase

R Red

Y Yellow B Blue Neutral Black

Ground Green or Yellow / Green

Size the conductor to limit drop voltage to a maximum of 5 %.

H.6.3 Execution

H.6.3.1 Installation

Wires:

- Install all line voltage wiring in conduit. Lighting and receptacle home runs indicated are for identification purposes only.
- Install no more than 6 conductors in one conduit. This excludes ground wire and the neutral conductor.
- Equipment where harmonic currents are present in the neutral conductor, i.e., electric discharge lighting, data processing, etc., neutral conductor shall be considered as a current-carrying conductor.
- Run panelboards and motor feeders in individual conduits.
- Ground all conduits, panelboards, receptacles, accessible fixtures, motors and motor equipment, etc. in accord with Section "Execution".
- Make ground continuity positive throughout entire project.
- Colour code all wires in accordance with Section, Basic Materials and Methods.

Cables:

- The cables shall be terminated at equipment, switchboards, isolators, etc., using appropriately sized mechanical cable glands, suitable for the type of cable and terminated in accordance with the manufacturer's instructions and recommendations.
- All metal gland parts shall be brass, bright dipped, and the gland shall consist of gland body with polychloroprene inner sheath sealing ring and captive polychloroprene outer sheath sealing ring, brass skid washer and earth tag.
- The gland shall be of such a design that during assembly no torque will be induced in the cable sheath.
- Each gland shall be locked onto equipment with suitable brass backnuts. Also, every gland shall have a polychloroprene shroud fitted over the gland for additional protection.
- Phase and neutral conductors shall be terminated onto equipment using bolted type fixing terminations which shall be fitted over and mechanically crimped to the conductors.
- No through joints will be permitted in L.V. cables where adequate manufacturer's lengths are available.

Cable Identification: The Contractor shall identify the ends of all power circuits.

At terminations, the Contractor shall identify each conductor of power circuits. Each cable marker shall bear the number of the corresponding circuit according to the Contractor's approved shop drawings. Markers shall be attached where the first individual conductor is routed away from the assembly. Each phase of multiphase power circuits shall be individually identified. Each marker shall be so attached that it is readily visible for circuit identification.

Moisture Seals: Each cable shall be kept sealed except when termination and splicing work is being performed. The ends of all cables shall be sealed with heat shrinkable caps. Cap sizes shall be as recommended by the cap manufacturer for the cable outside diameter and insulation. Caps shall contain sufficient adhesive that shrinkage of the cap during

application results in formation of a positive watertight seal capable of withstanding complete immersion or total exposure without permitting the entrance of moisture. Before and after pulling, the cable where the same are to be installed in conduits, the leading end seal of each length of cable shall be examined and repaired if necessary. All cut cable ends shall be promptly sealed after cutting except those to be spliced or terminated immediately.

Cable Ties: Lacing material for field installed cable shall be non-releasing nylon ties.

Branch circuit work: Originating from light and power panelboards is to be arranged as shown on the Contractor's approved shop drawings. loads on various phases of panelboards are to be balanced.

Control cables: May be fixed to racks, installed directly on cable trays or pulled in conduit and trunking indoors, and in underground ducts or in conduit outdoors.

Bunching of wires in raceways: Is to be in accordance with raceway filling factors permitted by the regulations.

Before pulling wires in conduits: Check that inside of conduit (and raceway in general) is free of burrs and is dry and clean.

Lubricants: Are to be used for pulling wire or cable if character of pull would otherwise damage conductors, insulation or jacket. Lubricants are to be approved by the Engineer.

Pull conductors into raceways: Simultaneously where more than one is being installed in the same raceway.

Support: Cables and wires pulled inside very high conduit risers are to be supported at upper end of risers and at intermediate points by split rubber grommets to relieve any stresses on conductors, where required.

Wiring at outlets: Leave a slack of at least 200 mm at each outlet.

Extra length: At every branch circuit outlet and pull-box, every cable passing through is to be left slack to allow inspection and for connections to be made. Cables terminating in outlet boxes are to be left with at least 250 mm extra length for terminations.

Joints or taps: In wires and cables, if permitted, are to be permanently accessible or made only in boxes or cabinet gutters.

Connectors:

- Connector – Type A-1: 2 Pressure indent type, for terminating or making T-taps and splices on conductors 10 mm and smaller. Connector is to be non-ferrous copper alloy applied to conductor by mechanical crimping pressure, with vinyl insulating sleeves or phenolic insulating covers.
- Connector – Type A-2:

Bolted pressure split type for terminating or making T-taps and splices on conductors 16 mm² and larger. Connector is to be cast non-ferrous copper alloy applied to conductor by clamping with minimum of two screws and provided with phenolic insulating cover.

- Connector – Type B-1:

Pre-insulated, spring type, for branch circuit and fixture wiring. Connector is to be steel encased spring with shell, insulated with vinyl cap and skirt.

Insulating covers: Are to be applied to prevent exposure of bare cable connections.

Switch legs: For local wall switches are to have distinctive colour, selected as complementary to cable colour coding used in the project.

Terminations: Conductors of wires and cables up to 16 mm² are to be tightly twisted and where possible doubled back before being clamped with set screws. Where two or more wires are looped into same terminals these conductors are to be tightly twisted together before inserting into terminals. In no case is bare conductor to be allowed to project beyond any insulated shrouding or mounting of a line terminal. Cables sizes 16mm² and larger are to terminate in tunnel lugs with set-screw, or by using bolted or sweated compression connectors.

Tagging: Tag main and feeder cables in pull-boxes, wireways and wiring gutters of panelboards or distribution cabinets. Tags are to identify cable or circuit number and conductor size in accordance with the schedules. Where two or more circuits are run to or through a control device, outlet box or ceiling junction box, each circuit is to be tagged as a guide in making connections.

Tighten:

Tighten electrical connectors and terminals including screws and bolts, in accordance with manufacturers published torque- tightening values. Where manufacturer's torquing requirements are not indicated, tighten connectors and terminals to comply with international standards.

H.7. CABLE TRUNKING

H.7.1 General

H.7.1.1 General Instruction

Works under this section shall be governed by conditions of contract and electrical works sections.

H.7.1.2 Scope

The Contractor shall supply and install trunking for cabling as shown on the Contractor's approved shop drawings and as herein specified. The system shall include, but not limited to standard rectangular trunking sections, bends, terminations, conversions, reducers, offsets, risers and all necessary parts to install a complete trunking system.

Manufacturer's standard fittings shall be used for all connections and changes in directions. Cutting and bending trunking to form flanges and attachments will not be permitted.

Standard lengths of trunking used shall not be less than two meters.

Cable retaining straps shall be fitted at intervals not exceeding 1 meter.

Where trunking passes through walls, floors, and ceilings, non combustible, non-metallic fire barriers shall be installed in the trunking.

Contractor shall re-verify the trunking sizes indicated on the Contractor's approved shop drawings and shall modify the same, if required, to allow the required wiring with a space factor of 45 per cent.

H.7.1.3 Codes & Standards

Metal trunking shall be manufactured generally in accordance with the requirements of BS 4678: Part 1. Metal thickness for body and cover material shall be at least as stipulated in Table 1 of BS 4678.

Trunking and connectors for internal use shall be finished with class 1 protection in according with BS 4678:Part 1. Where used externally, protection shall be class 3.

Coating shall comply with BS 729 or BS 3382:Part 2. Trunking shall be bonded to earth at several point connections, as required.

Construction of PVC trunking and its accessories shall comply with BS 4678:Part 4.

H.7.2 Products

H.7.2.1 Metal Trunking

Metal trunking shall be manufactured in accordance with the requirements of the codes and standard mentioned above. The metal thickness shall be at least as stipulated in table 1 of BS 4678.

Lengths of trunking shall be bonded to each other by using strip copper links not less than 12 mm wide x 1.5 mm thick and fixed with brass nuts, bolts and serrated washers. Lids shall be fixed at intervals not exceeding 1 metre by using quick release cam type fasteners. Steel screws and fasteners shall be protected against corrosion by a finish at least equivalent to zinc coating

Vertical trunking shall be supplied with cable support unit with insulated pins at intervals not exceeding 3 metre.

Horizontal trunking sizes exceeding 100 mm x 50 mm shall be supplied with cable separators with insulated pins at intervals not exceeding 2 metres.

All burrs rough edges caused due to any cutting or damage during erection shall be removed and the finish shall be made good. Corrosion patches if any, caused during storage and erection shall be removed and the affected area shall be treated with rust-proofing agent. Zinc rich epoxy primer of equivalent alternative shall be applied on the treated surfaces. In case of class 2 finishes this shall be followed by a coat of colour matching paint.

Any fixing used for securing or fitting shall not cause any long term corrosion or electrolytic action. Where brackets are used, they shall be constructed of mild steel angle or channel iron finished to the same standard as the trunking.

Connections to conduit, switchgear, junction boxes and distribution boards shall be made with flanged units.

A trunking joint shall be made where a trunking crosses an expansion joints.

The earth continuity links across such joints shall be of braided copper tape not less than 15 mm wide x 2 mm thick having a resistance from fixing to fixing equal to or less than the links used for standard trunking joints.

H.7.2.2 PVC Trunking

Trunking shall be made from high impact rigid PVC of thickness not less than 1.5 mm. Concealed trunking shall be of medium classification (IP42) and surface trunking shall be of heavy classification (IP53).

Lids shall be of the clip on type construction. All trunking accessories shall be of the same manufacturer. Site fabricated accessories shall not be acceptable.

Where the trunking is installed in ambient conditions higher than 25 degrees centigrade, trunking joints shall accommodate 7 mm expansion for every 6 metres of trunking run.

Protective conductor of not less than 2.5 mm² with green and yellow insulation shall be installed throughout the length of the trunking, to allow looping in and out of metallic equipment and accessories.

H.7.2.3 Skirting Trunking

Unless otherwise specified elsewhere, the trunking shall have three compartments one for power cables and the other for telephone and low current wires, as detailed on the Contractor's approved shop drawings.

Trunking body shall be manufactured from 1.2 mm nominal thickness zinc coated sheet steel in standard 2 meter lengths, with spot welded partition, each length supplied with one back connecting plate, one earthing strap, with plated

mushrooms head steel screws and shake proof washers. The cover fixings are secured by an internal fixing bridge and external fixing strap, both of which are mobile down the length of skirting to any given position, the covers shall be cut to suit on site. Metal work shall be finished metallic silver enamel inside and outside to receive site painters finished coat.

Skirting trunking shall have enough space for standard power socket outlets and telephone or data outlets both being screened and totally enclosed by sheet metal.

Skirting trunking elbows shall be easily installed wherever necessary on site. Similarly power socket outlets and telephone outlets shall be inserted at any place on the trunking with the same ease.

H.7.2.4 Dado Trunking

Dado trunking shall be manufactured from a minimum of 1.6 mm galvanised mild steel with 0001 mm zinc deposit and approved finished epoxy coated. Cover shall be of minimum 1.2 mm galvanised steel.

Fittings shall be manufactured from the same steel as body and covers with epoxy coated and matching colour. Socket/switch socket plates shall be provided as one or two gangs as required. Connector blocks with four pinching screws shall be provided as required.

Dado trunking shall have provision for compartmentation when used for power, low current and telephone / data system distribution

H.7.3 Execution

H.7.3.1 Supports

Trunking when run horizontally shall be securely supported at intervals not exceeding 1.5m, unless specially approved for supports at greater intervals, but in no case shall the distance exceed 3 m.

Trunking when run vertically shall be securely supported at intervals not exceeding 4.5 m and shall have not more than one joint between supports.

H.7.3.2 Installation

Trunking shall be securely fixed to floors walls, ceiling or multibeam trunk to the approval of the Engineer. It shall be installed such that it shall not be obstructed by other trades. Adjoining sections shall be securely fastened together to provide a rigid joint.

The sum of cross-sectional areas of all contained conductors shall not exceed 20% of the interior cross-sectional area of the trunking.

Trunking shall include all necessary cable retainers. Runs of trunking shall be parallel or perpendicular to walls and partitions.

H.8. BOXES AND FITTINGS

H.8.1 General

H.8.1.1 Description

General:

- Furnish all labour, materials, tools, equipment, and services for boxes and fittings in accord with provisions of Contract Documents.
- Completely coordinate with work of all other trades.
- Although such work is not specifically indicated, furnish and install all supplementary or miscellaneous items, appurtenances and devices incidental to or necessary for a sound, secure and complete installation.
- See General Requirements.

Related work specified elsewhere

- General Requirements.
- General Provisions for Electrical Works.

H.8.1.2 Submittals

Shop drawings: Required for Client and/or Engineer's review. B.

Product data: Required for Client and/or Engineer's review.

Samples: Required for Client and/or Engineer's review.

Project information: Manufacturer of listed products.

Contract closeout information: Required for Client and/or Engineer review.

H.8.2 Products

H.8.2.1 Materials

Acceptable manufacturers:

Products should conform with requirements of specifications.

Lighting outlet boxes: Hot-dip galvanized, 100 mm octagon.

- Use extension and plaster rings where required.
- Verify proper depth with partition thickness.
- Provide with proper fittings to support and attach lighting fixtures.
- Support outlet boxes for incandescent fixtures and other ceiling-mounting devices in lay-in acoustical tile ceilings by bar hangers anchored to ceiling construction members which do not interfere with tile removal.

Switch and receptacle boxes for concealed wiring: Hot-dip galvanized, including bar hangers for metal stud partitions.

Exposed switch and receptacle boxes: Corrosion resistant cast, ferrous metal, with threaded hubs.

Concealed gang-switch and junction boxes not dimensioned:

100 mm square, hot-dip galvanized, with bar hangers for metal stud partitions.

Boxes for 230 volt switches on opposite phases: Gang-switch type, with barriers between switches.

Weatherproof receptacle boxes: Corrosion resistant cast ferrous metal type, with threaded hubs and neoprene gasket.

Pull and junction boxes: Code-sized galvanized steel boxes provided with plain blank removable covers held in place with screws unless otherwise indicated. Where sizes are not indicated, use 100 mm square size.

Fittings and boxes with PVC coated steel conduit: Specified boxes and fittings with 40 mils minimum coating of PVC.

Pull and junction boxes in PVC conduit: 100 mm square moulded plastic boxes provided with means for securely terminating the conduits.

Conduit bodies: Corrosion resistant conduit fittings, cast ferrous metal type, of round series, with sharp clean threads.

EMT fittings: Compression-ring type, with cast malleable iron or pressure-cast bodies with tempered steel nuts. (Do not use indenter or set screw type EMT fittings).

Expansion joint fitting: Watertight deflection type.

Bushings: Threaded, galvanized, malleable iron.

Boxes used for all lighting outlets shall be fitted with steel insert clips to provide additional support for heavy pendants allow for heat conduction where totally enclosed fittings are used.

Grounding bushings: With screw termination for green grounding wire. All boxes shall be fitted with brass earthing terminals and brass inserts.

Outlet boxes shall be of size and design to suit the devices to be fitted thereto, such as telephone or socket outlets of the systems concerned.

H.8.3 Execution

H.8.3.1 Installation

Thread fittings for rigid conduit and IMC.

Install rigid conduits squarely into boxes. Rigidly clamp to box with locknut on outside and inside and provide bushing on inside.

Fill unused punched-out openings in boxes with proper closers manufactured for such purpose.

Use outlet boxes sized to accommodate quantity of conductors enclosed.

provide pull boxes or junction boxes in conduit runs where indicated or where required

to facilitate pulling of wires or making of connections. Make covers of all boxes accessible.

Mount outlet boxes for similar equipment at uniform heights within the same or similar areas without any restrictions by the Contractor's approved shop drawings or instructions on site.

In locating outlets, allowance shall be made for over head pipes, ducts, variations in arrangement, thickness of finish, window trim, paneling and other architectural construction. Any inaccuracy in locating outlets shall be corrected at no additional expense to the Client.

H.9. CABLE TRAYS

H.9.1 General

H.9.1.1 Related Documents

Drawings and general provisions of the Contract, including General and Supplementary Conditions and Specification Sections, apply to this Section.

H.9.1.2 Summary

This Section includes hot dip galvanized cable trays and accessories.

H.9.1.3 Submittals

Product Data: Include data indicating dimensions and finishes for each type of cable tray indicated.

Shop Drawings: For each type of cable tray. Show fabrication and installation details of cable tray, including plans, elevations, and sections of components and attachments to other construction elements. Designate components and accessories, including clamps, brackets, hanger rods, splice-plate connectors, expansion-joint assemblies, straight lengths and fittings.

Coordination Drawings: Floor plans and sections, drawn to scale. Include scaled cable tray layout and relationships between components and adjacent structural, electrical, and mechanical elements. Show the following:

- Vertical and horizontal offsets and transitions.
- Clearances for access above and to side of cable trays.
- Vertical elevation of cable trays above the floor or bottom of ceiling structure.

Field quality-control reports.

Operation and Maintenance Data: For cable trays to include in emergency, operation and maintenance manuals.

Source Limitations: Obtain cable tray components through one source from a single manufacturer.

Electrical Components, Devices and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

Comply with NFPA 70.

H.9.1.4 Delivery, Storage And Handling

Hot dipped galvanized steel cable tray may be stored outside without cover, but shall be loosely stacked, elevated off the ground, and ventilated to prevent staining during storage.

Store indoors to prevent water or other foreign materials from staining or adhering to cable tray. Unpack and dry wet materials before storage.

H.9.2 Products

H.9.2.1 Materials And Finishes

Cable Trays, Fittings, and Accessories: Steel, complying with NEMA VE 1 or BS EN ISO 1461 and BS EN 10142, 10143 and 10147.

Sizes and Configurations: Refer to the Cable Tray Sizes on Drawings for specific requirements for types, materials, sizes, and configurations.

Minimum thickness= 1.5mm.

- Center-hanger supports may be used with approval of Engineer.

H.9.2.2 Cable Tray Accessories

Fittings: Tees, crosses, risers, elbows, and other fittings as indicated, of same materials and finishes as cable tray.

Covers: Louvered type of same materials and finishes as cable tray.

Barrier Strips: Same materials and finishes as cable tray.

Cable tray supports and connectors, including bonding jumpers, as recommended by cable tray manufacturer.

H.9.2.3 Warning Signs

Lettering (40mm) high, black letters on yellow background with legend "Warning" NOT TO BE USED AS WALKWAY, LADDER, OR SUPPORT FOR LADDERS OR PERSONNEL"

Materials and fastening are specified in Section "Electrical Identification".

H.9.3 Execution

H.9.3.1 Cable Tray Installation

Cable trays shall be used for all multicore cables surface mounted.

Install as a complete system, including all necessary fasteners, hold-down clips, splice-plate support systems, barrier strips, hinged horizontal and vertical splice plates, elbows, reducers, tees and crosses.

Remove burrs and sharp edges from cable trays.

Fasten cable tray supports to building structure

- Place supports so that spans do not exceed maximum spans recommended by supplier.
- Construct supports from channel members, threaded rods, and other appurtenances furnished by cable tray manufacturer. Arrange supports in trapeze or wall-bracket form as required by application.
- Support bus assembly to prevent twisting from eccentric loading.
- Manufacture center-hung support if approved and authorized by the Engineer, designed for 60 percent versus 40 percent eccentric loading conditions, with a safety factor of 3.
- The cable trays shall be of sufficient width to take all cables without crowding and shall allow for possible future additions to the proportions of the present requirements. Spare capacity shall be 35% minimum. Cables shall be run singly and stacking will not be permitted.
- Cable trays fixed to walls or flat ceilings shall be installed with the flange outwards or downwards respectively to suit and shall be fixed with an approved fixing with spacing and washers such that the tray is at least 25mm from the surface of the wall or ceiling. Earth continuity shall be maintained between each section of cable tray and total run of tray shall be effectively bonded to the nearest earth continuity conductor at both ends.
- Cable trays installed on roof floor or in any other floor where exposed to sun rays shall be protected with size shade covers (asbestos not approved)

Make connections to equipment with flanged fittings fastened to cable tray and to equipment. Supports cable tray independent of fittings. Do not carry weight of cable tray on equipment enclosure.

Install expansion connectors where cable tray crosses buildings expansion joint

Make changes in direction and elevation not cutting of tray shall be permitted.

Seal penetrations through fire and smoke barriers according to Section "Through-Penetration Firestop Systems."

Sleeves for Future Cables: Install capped sleeves for future cables through firestop-sealed cable tray penetrations of fire and smoke barriers.

Workspace: Install cable trays with enough space to permit access for installing cables.

Install barriers to separate cables of different systems, such as power, communications, and data processing; or of different insulation levels, such as 600, 5000, and 15 000 V.

After installation of cable trays is completed, install warning signs in visible locations on or near cable trays .

H.9.3.2 Cable Installation

Install cables only when cable tray installation has been completed and inspected.

Fasten cables on horizontal runs with cable clamps or cable ties. Tighten clamps only enough to secure the cable, without indenting the cable jacket. Install cable ties with a tool that includes an automatic pressure-limiting device.

On vertical runs, fasten cables to tray every (45mm). Install intermediate supports when cable weight exceeds the load-carrying capacity of the tray rungs.

In existing construction, remove inactive or dead cables from cable tray.

Install covers after installation of cable is completed.

Wherever the cable trays are exposed to outside conditions, i.e. lay on the roof, these shall be covered with galvanized steel sheet of 20 gauge to protect from heat and rain.

H.9.3.3 Connections

Install an insulated equipment-earthing conductor with cable tray, in addition to those required by IEC. Earth Continuity shall be maintained between each section of tray and total run of tray shall be effectively bonded to nearest Earthing bar at both ends.

H.9.3.4 Field Quality Control

After installing cable trays and after electrical circuitry has been energized, survey for compliance with requirements. Perform in two stages the following field quality-control survey in two stages: Stage 1: after completion of cable tray installation Stage 2 after completion of cables installation

- Visually inspect cable insulation for damage. Correct sharp corners, protuberances in cable tray, vibration, and thermal expansion and contraction conditions, which may cause or have caused damage.
- Verify that the number, size, and voltage of cables in cable tray do not exceed that permitted by NFPA 70. Verify that communication or data-processing circuits are separated from power circuits by barriers.
- Verify that there is no intrusion of such items as pipe, hangers, or other equipment that could damage cables.
- Remove deposits of dust, industrial process materials, trash of any description, and any blockage of tray ventilation.
- Visually inspect each cable tray joint and each ground connection for mechanical continuity. Check bolted connections between sections for corrosion.
- Check for missing or damaged bolts, bolt heads, or nuts. When found, replace with specified hardware.
- Perform visual and mechanical checks for adequacy of cable tray grounding; verify that all takeoff raceways are bonded to cable tray.

Report results in writing.

H.9.3.5 Protection

Protect installed cable trays.

- Repair damage to galvanized finishes with zinc-rich paint recommended by cable tray manufacturer.

- Repair damage to PVC or paint finishes with matching touchup coating recommended by cable tray manufacturer.
- Install temporary protection for cables in open trays to protect exposed cables from falling objects or debris during construction. Temporary protection for cables and cable tray can be constructed of wood or metal materials until the risk of damage is over.

H.10. WIRING DEVICES

H.10.1 General

H.10.1.1 Description

General

- Furnish all labour, materials, tools, equipment, and services for wiring devices, in accord with provisions of Contract Documents.
- Completely coordinate with the work of other trades.
- Although such work is not specifically indicated, furnish and install all supplementary or miscellaneous items, appurtenances and devices incidental to or necessary for a sound, secure and complete installation.
- See General Requirements.

Related work specified elsewhere:

- General Requirements.
- General Provisions for Electrical Works.

H.10.1.2 Submittals

Shop drawings: Required for Client and/or Engineer's review, including, but not limited to the following:

- Exact indication of position of each item and outlet box and fitting on layout drawings, with box and equipment types and sizes.
- Installation details of special items including isolating switches, fans, etc.
- Wiring diagrams of special items.

Product data: Required for Client and/or Engineer's approval. Submit samples of each type of device, unless otherwise agreed in written by the engineer.

Samples: Required for Client and/or Engineer's review.

Project information: Manufacturer of listed products.

Contract close out information: Test report of grounding continuity, polarity and retention force for each receptacle.

H.10.2 Products

H.10.2.1 Materials - General

All goods and products covered by these specifications shall be submitted for Engineer's prior approval to confirm the compliance of these goods and products with the requirements set in these Specifications including, but without any limitation, the general requirements .

H.10.2.2 Switches

Lighting switches: generally shall be quiet-operating flush toggle type lighting switches for back and side wiring, 16 Amp(European) 20 Amp(British), 230 V a.c with white plate for indoor installations in general, unless otherwise indicated. Types: single, tow-way or intermediate, single pole or double pole as shown on the Contractor's approved shop drawings.

Push button switch: as type (A) but with push button control (push to make, push to break).

Weather proof switch: for installation in wet areas, with weather proof plate, synthetic gasket, weather proof outlet box, on/off indication, IP-56 enclosure.

Double pole switch: tumbler operated, to BS 3676, with moulded plastic plate, marked (etched) with equipment controlled like hand dryer. Switch is to be mounted to flush box and provided with cord outlet and cord extension to equipment controlled.

Multi gang grid lighting switch: 16 Amp(European) 20 Amp(British), 230 V a.c rocker operated with phase barrier and aluminum coated surface plate for specified number of gangs.

Switches with pilot light in red toggle handle: Quiet-type, 20 amp, 230 volts AC. Handle to light when switch is on where indicated on plans.

Narrow switches for hollow metal jamb posts: 16 amp "Specification Grade," quiet- operating, toggle type ivory or as required.

H.10.2.3 Socket Outlets

Generally: to have injection moulded plastic base with self-adjusting, non-expanding contacts to prevent permanent distortion, arranged for side and/or back connection and with screw terminals accepting at least three parallel branch-circuit wires.

Types: general purpose socket outlets are to conform with DIN 49440 or other standard European practice. Shall be generally 13A or 16A, 250 V a.c, wire grounding, single.

Duplex sockets: are to be mounted in parallel under one common plate with break-off feature of two circuit connection.

Weatherproof socket outlet:

- 2 pole plus earth, enclosed in surface mounted moulded box and with cover comprising spring-retained gasketted hinged flap for use in general in wet areas except in pantries.
- Same but of IP 44-7, flush mounted for use in pantries.
- Single phase, two pin with side earthing, two wire with 4 mm round pins at 19 mm centers in accordance with German Standards, complete with back box.

Flush in floor receptacles: shall be generally 16 A, 230 V, 3 wire, grounding type, dual fully adjustable box with power fitting and brass carpet flange, adequate to the respective floor.

Special purpose receptacles Special purpose receptacle shall be generally 2 pole, 3 wire grounding, side and back wired, single, adequately rated to the respect device / equipment. Power socket outlet 400 V service single outlet, 3P+E, 3 phase, polarized, earthing type, rated 32 A, 400 V, to BS 4343 and IEC 309, with splash proof cast metal box and hinged spring-return plate, and with matching plug 3P+E.

Plugs: compatible with type of socket outlet specified, break resistant, of impact resistant moulded insulating material (separable construction), with solid brass pins and cord grip and of shape providing easy hand-grip of removal.

Fuses for standard British type sockets are to be standard 13 A cartridge fuses fitted in plug.

H.10.2.4 Switch Disconnecter (Disconnecting Switch)

Rating: 500 V, 2, 3, 3+N or 4 Pole, load break, short-circuit make, in accordance with IEC 408, utilization category 22 for heating and lighting loads, category 23 for motor circuits, and with ampere rating shown on the Contractor's approved shop drawings.

Design: non-fusible, air-break switch disconnecter, single throw, safety type, housed in separate metallic enclosure with arc quenching devices on each pole, making it capable of interrupting at least six times the isolator's rated current. Isolators shall effectively interrupt the power supply for all line conductors and neutral (where it exists), and simultaneously disconnect the supply for control circuits.

Operating mechanism: quick-make, quick-break, independant of operator, with external operating handle mechanically interlocked to prevent opening door unless switch is in open position. Switch disconnecter is to have provision for by-passing interlock. Position of handle is to be positive and clearly indicated on cover.

Enclosure: general purpose sheet steel for indoor use IP 42, and weather-proof type cast-metal or sheet steel for outdoor installations IP 65, unless otherwise required or shown on the Contractor's approved shop drawings. Locking of operating handle is to be possible in open and closed positions.

H.10.2.5 Lighting Contactors

Double pole for single phase and neutral circuits, and triple pole for three phase circuits, mechanically held, electrically operated, rated 500 V, of current ratings as required complying with IEC-581-1 category AC 2 and AC 3.

Contacts: copper alloy, with silver cadmium alloy double break contacts designed for switching inductive ballast loads and switching of tungsten lamp loads.

Auxiliary contacts: with one N.O. and one N.C. spare contacts.

H.10.2.6 Device Plates

Device plates for concealed wiring: Same manufacturer as devices, to suit device covered, single or ganged in one piece with beveled edges that match faces of plates.

- Flush impact resistant colour to match device covered.
- Narrow plates for hollow metal jamb posts: stainless steel.
- Permanently mark all emergency system receptacle plates to indicate panelboard and circuit number supplying them.
- Approval shall be obtained from Client and/or Engineer prior to placement of order. Device plates for surface type cast-metal boxes: Corrosion resistant cast ferrous metal designed for application.

H.10.3 Execution

H.10.3.1 General

Locate devices as indicated and as scheduled in Section General provisions.

Center outlets with regard to paneling, furring, trim, etc.

Where several outlets occur in a room, symmetrically arrange them.

Any outlet which is improperly located must be corrected at Contractor's expense.

Set outlets plumb or horizontal and extending to finished surface of wall, ceiling or floor as case may be without projecting beyond same.

H.10.3.2 Locations

The drawings generally show approximate locations of outlets and equipment. Exact locations are to be determined from interior finishing and detail drawings. Any condition that would place an outlet in an unsuitable location is to be referred to the Engineer. Locate switches at strike sides of doors, whether shown on the Contractor's approved shop drawings or not. In locating outlets allow for overhead pipes, ducts, variations in arrangement, thickness of finishings, window trim, panelling and other architectural features.

Mounting heights for outlet boxes and similar equipment are to be uniform within the same or similar areas. Mounting is to be as shown on the Contractor's approved shop drawings or as approved by the Engineer. Unless otherwise shown or instructed, mount lighting switches and socket outlets generally at 1200 mm and 300 from finished floor level respectively.

Single pole switched are to switch the phase wire. Do not run neutral wire through switches having neutral shunt or bridge.

Additional outlets to those shown on the Contractor's approved shop drawings are to be provided as required by equipment manufacturers for control or other wiring.

Recessed outlet boxes: make neat openings, to the satisfaction of the Engineer, allowing for thickness of finishings, and use extension rings if required. Repair damaged finishings to original condition before installation of fittings or plates.

Grouped outlets: arrange neatly so that use of fittings is convenient and clear.

Waterproof fittings: follow manufacturer's instruction for installation and connection to conduit system to fully achieve required degree of protection.

Damaged fittings: reject damaged fittings or plates with damaged finish. Protect fittings and plates against damage after installation and until handed over.

Connection of appliances: Where appliance is designed to adapt directly to outlet box, extend electrical wiring to incoming terminals inside appliance. Where appliance is not designed to adapt to outlet box, install connecting wiring in flexible conduit firmly fixed to outlet box cover plate and to terminal box on appliance.

H.10.3.3 Inspection and Tests on Site

Visual inspection: fittings and equipment are to be inspected for fixing and workmanship.

Megger tests: are to include switch and socket outlet tests together with insulation resistance of wiring installations.

Operation: devices are to be tested for operation and are to perform as intended at full load without any signs of heating.

Equipment: is to be insulation tested and observed, under full-load for not less than 3 days operation, with respect to under heating and performance in general.

H.11. ELECTRICAL IDENTIFICATION

H.11.1 General

H.11.1.1 Section Includes

Nameplates and labels. Wire and cable markers. Conduit markers.

H.11.1.2 Related Sections

Painting.

H.11.1.3 Submittals

Product Data: provide catalog data for nameplates, labels, and markers.

Manufacturer's Instructions: Include instructions for storage, handling, protection, examination, preparation and installation of product.

H.11.1.4 Regulatory Requirements

Conform to regulations for electrical installations issued by "The Institution of Electrical Engineers" IEE.

H.11.1.5 Extra Materials

Furnish under General provisions.

H.11.2 Product

H.11.2.1 Nameplates and Labels

Nameplates: Engraved three - layer laminated plastic, [black] letters on [white] background.

Equipment nameplates are to be non-corroding, robust metal, inscribed in Arabic and English, and finally fixed to equipment at factory. Nameplates are to indicate names and address of manufactures, model, serial number, basic characteristics and ratings of equipment and are to include elementary diagrams etc., all in accordance with the standards. Locations:

- Each electrical distribution and control equipment enclosure.
- Communication cabinets.
- Other as necessary.

Letter size:

- Use 3 mm letters for identifying individual equipment and loads.
- Use 6 mm letters for identifying grouped equipment and loads. Labels: Embossed adhesive tape, with 5 mm white letters on [black] background. Use only for identification of individual wall switches and receptacles, control device stations, and others as applicable.

H.11.2.2 Wire Markers

Description: split sleeve or tubing type wire markers.

Locations: at panelboard gutters, pull boxes, outlet and junction boxes, and load connection.

Legend:

- Power and lighting circuits: branch circuit or feeder number indicated on drawings.
- Control circuits: control wire Number indicated on schematic and interconnection diagrams on drawings.

H.11.2.3 Underground Warning Tape

Description: 100 mm wide plastic tape, detectable type, colored [red] [yellow] with suitable warning legend describing buried electrical lines.

H.11.3 Execution

H.11.3.1 Preparation

Degrease and clean surfaces to receive nameplates and labels.

H.11.3.2 Application

Install nameplate and label parallel to equipment lines.

Secure nameplate to equipment front using screws, rivets, or adhesive.

Secure nameplate to inside surface of door on panelboard that is recessed in finished locations.

Paint colored band on conduit longer than 2 m.

Paint bands 6 m on center.

Color:

- Fire alarm system: (red)
- Other: black or gray.

Identify underground conduits using underground warning tape. Install one tape per trench.

H.12. ENGINE GENERATOR SET

H.12.1 General

H.12.1.1 General

The emergency power generators and controls system will consist of engine generators with their individual set mounted digital control units, one master digital control unit mounted alone or inside the totalizer board and required local command units mounted on each set. The units shall be designed to properly interface with the number of remotely located load connection contactors and automatic transfer switches in number as shown on the Contractor's approved shop drawings. All equipment supplied shall be new and unused, and designed to meet all applicable NEMA, ANSI, IEEE and NFPA-76A, BSS standards.

Ratings of generator set smaller than rating shown on the Contractor's approved shop drawings are strictly prohibited.

H.12.1.2 Related Documents

Drawings and general provisions of the Contract, including General and Supplementary Conditions, apply to this Section.

H.12.1.3 Summary

This section includes packaged engine-generator sets for emergency power supply with the following features:

- Diesel engine with Alternator.
- Unit-mounted cooling system.
- Unit-mounted control and monitoring.
- Performance requirements for sensitive loads.
- Load banks.

Related Sections include the following: Section “Transfer Switches” for transfer switches including sensors and relays to initiate automatic -starting and stopping signals for engine-generator sets.

H.12.1.4 Definition

Operational Bandwidth: The total variation from the lowest to highest value of a parameter over the range of conditions indicated, expressed as a percentage of the nominal value of the parameter.

H.12.1.5 Submittals

Product Data: For each type of packaged engine generator indicated. Include rated capacities, operating characteristics, and furnished specialties and accessories. In addition, include the following:

- Thermal damage curve for generator.
- Time-current characteristic curves for generator protective device.

Shop Drawings: Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.

- Dimensioned outline plan and elevation drawings of engine-generator set and other components specified.
- Design Calculations: Signed and sealed by a qualified professional engineer. Calculate requirements for selecting vibration isolators and seismic restraints and for designing vibration isolation bases. The Engineer shall be from the DG set manufacturer or from Authorized agent.
- Vibration Isolation Base Details: Signed and sealed by a qualified professional engineer. Details fabrication, including anchorages and attachments to structure and to supported equipment. Include base weights.
- Wiring Diagrams: Power, signal and control wiring.

Manufacturer Seismic Qualification Certification: Submit certification that engine-generator set, batteries, battery racks, accessories and components will withstand seismic forces defined in Section “Electrical Supports and Seismic Restraints.” Include the following:

- Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation. a. The term “withstand” means “the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified”. b. The term “withstand” means “the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event.”
- Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
- Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

Qualification Data: For installer, manufacturer and testing agency.

Source quality-control test reports.

- Certified summary of prototype-unit test report.
- Certified Test Reports: For components and accessories that are equivalent, but not identical, to those tested on prototype unit.
- Certified Summary of performance Tests: Certify compliance with specified requirement to meet performance criteria for sensitive loads.
- Report of factory test on units to be shipped for this Project, showing evidence of compliance with specified requirements.
- Report of sound generation.
- Report of exhaust emissions showing compliance with applicable regulations.
- Certified Torsional Vibration Compatibility: Comply with NFPA 110.
- Field quality-control test reports.

Operation and Maintenance Data: For packaged engine generators to include in emergency, operation and maintenance manuals. In addition to items specified in Section “Operation and Maintenance Data ,”include the following:

- List of tools and replacement item recommended to be stored at Project for ready access. Include part and drawing numbers, current unit prices, and source of supply.

Warranty: Special warranty specified in this Section.

H.12.1.6 Quality Assurance

Installer Qualifications: Manufacturer’s authorized representative who is trained and approved for installation of units required for this Project. The DG set Engine, Alternator and the synchro (locally mounted on units and the master panel) Control Panel shall be the standard product of one single manufacturer with single source warranty.

- Maintenance Proximity: Not more that four- hour’s normal travel time from installer’s place of business to Project site.
- Engineering Responsibility: Preparation of data for vibration isolators and seismic restraints of engine skid mounts, including Shop Drawings, based on testing and engineering analysis of manufacturer’s standard units in assemblies similar to those indicated for this Project.

Manufacturer Qualifications: A qualified manufacturer. Maintain, within 30Km of project site, a service center capable of providing training, parts and emergency maintenance repairs.

Testing Agency Qualifications: An independent agency, with the experience and capability to conduct the testing indicated, that is a member company of the Association sets of the officially approved Bureau de Controle operating in Lebanon Source Limitations: Obtain packaged generator sets and auxiliary components through one source from a single manufacturer.

Electrical Components, Devices and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction and marked for intended use. Comply with ASME B15.1.

Comply with NFPA 37.

Comply with NFPA 70.

Comply with NFPA 99.

Comply with NFPA 110 requirements for Level (2) emergency power supply system.

Comply with UL 2200.

Engine Exhaust Emissions: Comply with applicable Lebanese government requirements.

Noise Emission: Comply with local governmental requirements for maximum noise level at adjacent property boundaries due to sound emitted by generator set including engine, engine exhaust, engine cooling-air intake and discharge, and other components of installation.

H.12.1.7 Project Conditions

Environmental Conditions: Engine-generator system shall withstand the following environmental conditions without mechanical or electrical damage or degradation of performance capability:

- Ambient Temperature: (50 deg C).
- Relative Humidity: 0 to 95 percent.
- Altitude: Sea level to 0m.

H.12.1.8 Coordination

Coordinate size and location of concrete bases for package engine generators. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified in Structural Specification.

Coordinate size and location of roof curbs, equipment supports, and roof penetrations for remote radiators. These items are specified in Structural Specification.

H.12.1.9 Warranty

Special Warranty: Manufacturer's standard for in which manufacturer agrees to repair or replace components of packaged engine generators and associated auxiliary components that fail in materials or workmanship within specified warranty period.

- Warranty Period: 2 years from date of Substantial completion.

H.12.1.10 Maintenance Service / Local Representative

Initial Maintenance Service: Beginning at Substantial Completion, provide 12 months full maintenance by skilled employees of manufacture's designated service organization. Include quarterly exercising to check for proper starting, load transfer, and running under load. Include routine preventive maintenance as recommended by manufacturer and adjusting as required for proper operation. Provide parts and supplies same as those used in the manufacture and installation of original equipment.

H.12.1.11 Local Representatives

Provide evidence that proposed equipment manufacturer has a locally established and authorized organization which can be called upon for professional advice and maintenance as may be required, and which can immediately supply spare parts to support day to day and emergency maintenance requirements. Failure to satisfy the Engineer may disqualify

H.12.1.12 Maintenance Contract

Obtain an undertaking by the equipment manufacturer and his authorized local representative to provide an annual maintenance contract, available after substantial completion of the work, covering routine service and emergency service by trained employees, and to ensure supply of necessary standard spare parts.

The supplier to provide the original catalogues of the O&M with the generator before starting installation of the gensets.

H.12.1.13 Extra Materials

Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

- Fuses: One for every 10 of each type and rating, but no fewer than one of each.
- Indicator Lamps: Two for every six of each type used, but no fewer than two of each.
- Filters: One set each of lubricating oil, fuel, and combustion-air filters.

H.12.1.14 Equipment Data

Submit full technical data of equipment for approval including, but not limited to, the following:

General description and characteristics of engine- generating sets, standards with which components comply, site rating and overload capability, overall efficiency, and fuel and lubricant consumption at 100%, 75%, 50% and 25% of rated load

Description and operating criteria of engine; type, model, manufacturer, fuel and lubricating oil types and specific consumption, starting conditions and starting periods from cold to full-load pick-up, governor and response characteristics due to sudden load changes, super-charger, fuel injection system, cooling system and radiator, air filters, fuel filters, oil filters and pumps

Description and operating criteria of generator, exciter and voltage regulator, with loading response and short-circuit characteristics, insulation, cooling and accessories dimensions, weights and forces, mounting methods, vibration protection etc.

Battery type, make, charge/discharge characteristics, capacity and constructional features

Battery charger, method of charging, equalizing and trickle charging

Fuel tanks, pipes and accessories; materials and construction

Exhaust system and silencers; materials and construction

Control instruments, protection, alarms, cut-outs, indicating lamps, indicating instruments and all other devices or components

Synchronization system where two or more sets are in parallel, including technical data, instruments, governor and voltage regulation, with characteristic curves etc.

Calculated noise levels in dBA at typical points within engine room and at various locations inside and outside.

H.12.1.15 Shop And Construction Drawings

Submit drawings for approval including, but not limited to, the following:

Certified manufacturers' dimensional drawings, templates and installation instructions for equipment and accessories, showing weights and distribution of forces, location and size of cabling (power and control), piping connections to equipment, and other pertinent data

Plans and elevations of all equipment

Separate unit wiring diagrams, schematics and interconnecting wiring diagrams

Constructional details of bulk fuel storage tanks and daily service fuel tank, including outline drawings showing piping arrangements, connections and dimensions

Complete execution drawings of associated auxiliaries.

H.12.1.16 Compliance Review

Bidding Manufacturer shall provide a Compliance Review of generator room and installation plans and specifications. The first section of the Compliance Review shall be a review of the plans. The second section shall be a paragraph-by-paragraph review of the specifications with the following information, "C", "D" or "E" marked in the margin of the original specification and any subsequent addendums.

- "C": Comply with no exceptions.
- "D": Comply with deviations. For each and every deviation, provide a numbered note with reasons for the proposed deviation and how the intent of the specification can be satisfied.
- "E": Exception, do not comply. For each and every exception, provide a numbered note with reasons and possible alternatives.

Unless a deviation or exception is specifically noted in the Compliance Review, it is assumed that the manufacturer is in compliance with the plans and specifications. Deviations or exceptions taken in cover letters, subsidiary documents or by omission or by contradiction do not release the manufacturer from being in compliance unless the exception or deviation has also been specifically noted in the Compliance Review.

H.12.1.17 Spare Parts

Provide manufacturer's recommended spare parts for 1000 hours of operation and shall be submitted for approval with the supplier's offer. Provide list of manufacturer's spare parts for 2000 hours operation together with current prices.

H.12.1.18 Tools and Instruments

Provide tools and instruments required for normal routine inspection, testing, operation and general maintenance, as recommended by the manufacturer.

H.12.2 Products

H.12.2.1 Manufacturers

Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:

Manufacturers: Subject to compliance with requirements, provide products by one of the following:

Basis-of-Design Product: Subject to compliance with requirements, provide (the product indicated on Drawings) a comparable product by one of the following:

- Caterpillar: Engine Div. (Ireland)
- Wilson (UK only)
- Cummins Generation, Industrial Business Group (UK Only)
- SDMO. (France)
- Kohler (USA Only)

H.12.2.2 General

Diesel Engine-Generator Set: 4 cycle, 1500 rpm, diesel engine generator set (Each unit shall be prime rated with 10% overload capability for one hour every twelve hours) as shown on the Contractor's approved shop drawings. Generator

set ratings: as shown on the Contractor's approved shop drawings at 0.8 PF, rating based on site conditions noted below. System voltage of: 400 volts AC, Three phase, Four-wire, 50 hertz. Site Conditions: ambient temperatures up to 40 degrees C.

Two-cycle engine are not approved.

The generator set shall include inherent over current, short circuit and overload protection, digital and analog AC metering equipment, sensor failure detection, and remote monitoring and control capability. No exceptions or deviations to these requirements will be permitted.

All necessary interface units and contacts to be provided with BMS-for status indication only

MINIMUM TIME INTERVAL BETWEEN TWO SUCCESSIVE OVERHAUL PERIOD SHALL BE CERTIFIED TO BE NOT LESS THAN 15000 HOURS.

LOCALLY ASSEMBLED GENERATOR SETS ARE STRICTLY PROHIBITED.

all synchro / control panels shall be manufactured by same manufacturer of generator. synchro panels from any other supplier, including approved switchboard local panel makers are strictly prohibited.

bidder shall be fully responsible to provide at no extra cost all necessary extra fans – other than the ones included in the mechanical works -, bidder shall be responsible to include in his price, all the necessary proper ventilation of the room after verifying design conditions of room.

Ventilation (at no extra cost) shall ensure a maximum radiator coolant temperature of 90 DEG C.

The installation of the generator in basement shall closely coordinated during construction stage and shall consider the maximum allowable structural capacity of ramps. Contractor shall secure at no extra cost dismantling of generator set (installing radiator separately) in coordination with generator vendor.

All breakers, contactors, controls used in this package shall strictly abide with the specifications of those same in other sections of this book of specifications.

The generator package shall also include all necessary interface cards, RS485 connection with a dedicated PC, which allows remote measurement and status indication of all the parameters and variables that can be read on the generator engine local panels. The PC shall be part of this Contract's package.

A 2 KVA UPS shall be provided (2 UPS's in parallel or hot standby combination with 2 hours battery autonomy) for supplying power to the dampers and all necessary controls in the generator room.

Generator bidder shall submit separate quotation part of this contract for a complete dust particle and fume cleaning system similar either to Cyclone or DCL.

The horsepower of the engine at its minimum tolerance level shall be sufficient to drive the alternator and all connected accessories. Engine accessories and features shall include:

An electronic governor system shall provide automatic isochronous frequency regulation. The engine governing system shall not utilize any exposed operating linkage.

Skid-mounted radiator and cooling system shall be provided and be rated for full load operation in 40 degrees C ambient as measured at the generator air inlet. Radiator shall be provided with a duct adaptor flange. The cooling system shall be filled with 50/50 ethylene glycol/water mixture by the equipment supplier. Rotating parts shall be guarded against accidental.

The following elements shall be provided:

- An electric starter capable of three complete cranking cycles without overheating.
- Positive displacement, mechanical, full pressure, lubrication oil pump. Full flow lubrication oil filters with replaceable spin-on canister elements and dipstick oil level indicator.
- An engine driven, mechanical, positive displacement fuel pump. Fuel filter with replaceable spin-on canister element.
- Replaceable dry element air cleaner with restriction indicator.
- Flexible supply and return fuel lines.

Engine mounted, thermostatically controlled, water jacket heater(s) for each engine. The heater(s) shall be sized as recommended by the generator set manufacturer. Heater voltage shall be as shown on the project the Contractor's approved shop drawings.

H.12.2.3 Engine Generator Set

Factory-assembled and tested, engine generator set.

Mounting Frame: Maintain alignment of mounted components without depending on concrete foundation, and have lifting attachments.

- Rigging Diagram: Inscribed on metal plate permanently attached to mounting frame to indicate location and lifting capacity of each lifting attachment and generator-set center of gravity.

Capacities and Characteristics:

- Power Output Ratings: Nominal ratings as indicated (Prime rating).
- Output Connections: Three-phase, (three)(four) wire.
- Nameplates: For each major system component to identify manufacturer's name and address, and model and serial number of component.

Generator-Set Performance:

- Steady-State Voltage Operational Bandwidth: 3 percent of rated output voltage from no load to full load.
- Transient Voltage Performance: Not more than 20 percent variation for 50 percent step-load increase or decrease. Voltage shall recover and remain within the steady-state operating band within three seconds. - Voltage regulation: $\pm 0.5\%$ from no load to full load. - Voltage drift: $\pm 0.5\%$ for 60°F (33°C) change in ambient over eight (8) hours with temperature stabilization at each point. - Random voltage variation: For constant loads from no load to full load will not exceed $\pm 0.5\%$ of its mean value.
- Steady-State Frequency Operation Bandwidth: 0.5 percent of rated frequency from no load to full load.
- Steady-State Frequency Stability: When system is operating at any constant load within the rated load, there shall be no random speed variations outside the steady-state operational band and no hunting or surging of speed.
- Transient Frequency Performance: Less than 5 percent variation for 50 percent step-load increase or decrease. Frequency shall recover and remain within the steady-state operating band within five seconds.
- Output Waveform: At no loads harmonic content measured line to line or line to neutral shall not exceed 5 percent total and 3 percent for single harmonics. Telephone influence factor, determined according to NEMA MG 1, shall not exceed 50 percent.
- Sustained Short-Circuit Current: For a 3 phase, bolted short circuit at system output terminals, system shall supply a minimum of 250 percent of rated full-load current for not less than 10 seconds and then clear the fault automatically, without damage to generator system components.

- Start Time: Comply with NFPA 110, Type 10, system requirements.
- The diesel engine-generator set shall be capable of single step load pick up of 100% nameplate kW and power factor, less applicable derating factors, with the engine-generator set at operating temperature.
- Motor starting capability shall be a minimum of twice the KVA rating of the generator. The generator set shall be capable of sustaining a minimum of 70% of rated no load voltage with the specified kVA load at near zero power factor applied to the generator set.

Generator-Set Performance for Sensitive Loads:

- Steady-State Voltage Operational Bandwidth: 1 percent of rated output voltage from no load to full load.
- Transient Voltage Performance: Not more than 10 percent variation for 50 percent step-load increase or decrease. Voltage shall recover and remain with the steady-state operating band within 0.5 second.
- Steady-State Frequency Operational Bandwidth: Plus or minus 0.25 percent of rated frequency from no load to full load.
- Steady-State Frequency Stability: When system is operating at any constant load within the rated load, there shall be no random speed variations outside the steady-state operations band and not hunting or surging of speed.
- Transient Frequency Performance: Less than 2-Hz variation for 50 percent step-load increase or decrease. Frequency shall recover and remain with the steady-state operating band within three seconds.
- Output Waveform: At no load, harmonic content measured line to neutral shall not exceed 2 percent total with no slot ripple. Telephone influence factor, determined according to NEMA MG1, shall not exceed 50 percent.
- Sustained Short-Circuit Current: For a 3-phase, bolted short circuit at system output terminals, system shall supply a minimum of 300 percent of rated full-load current for not less than 10 seconds and then clear the fault automatically, without damage to winding insulation or other generator system components.
- Excitation System: Performance shall be unaffected by voltage distortion caused by nonlinear load. Provide permanent magnet excitation for power source to voltage regulator.
- Start Time: Comply with NFPA 110, Type 10, system requirements

H.12.2.4 Prototype Tests and Evaluation

Prototype tests shall have been performed on a complete and functional unit, component level type tests will not substitute for this requirement.

A witnessed test shall be performed on gensets in factory of origin and shall be attended by two engineers selected by Client or Consultant. Testing shall include all the paralleling and load sharing + load shedding functions with dummy loads similar to project load. Bidder who do not include this factory witnessed testing will not be considered.

H.12.2.5 Generator

AC Generator: The AC generator shall be; synchronous, four pole, 2/3 pitch, revolving field, drip-proof construction, single pre-lubricated sealed bearing, air cooled by a direct drive centrifugal blower fan, and directly connected to the engine with flexible drive disc.

All insulation system components shall meet NEMA MG1 temperature limits for Class H insulation system. Actual temperature rise measured by resistance method at full load shall not exceed 125 degrees Centigrade.

The generator shall be capable of delivering rated output (kVA) at rated frequency and power factor, at any voltage not more than 5 percent above or below rated voltage.

A permanent magnet generator (PMG) shall be included to provide a reliable source of excitation power for optimum motor starting and short circuit performance. The PMG and controls shall be capable of sustaining and regulating current supplied to a single phase or three phase fault at approximately 300% of rated current for not more than 10 seconds.

Any other excitation method different from PMG shall be rejected.

H.12.2.6 Generator, Exciter, and Voltage Regulator

Comply with NEMA MG 1.

Drive: Generator shaft shall be directly connected to engine shaft. Exciter shall be rotated integrally with generator rotor.

Electrical Insulation: Class H or Class F.

Stator-Winding Leads: Brought out to terminal box to permit future reconnection for other voltages if required.

Construction shall prevent mechanical, electrical and thermal damage due to vibration, over speed up to 125 percent of rating, and heat during operation at 110 percent of rated capacity.

Enclosure: Drip proof.

Instrument Transformers: Mounted within generator enclosure.

Voltage Regulator: Solid-state type, separate from exciter, providing performance as specified.

- Adjusting rheostat on control and monitoring panel shall provide plus or minus 5 percent adjustment of output-voltage operating band.

Strip Heater: Thermostatically controlled unit arranged to maintain stator windings above dew point.

Windings: Two-thirds pitch stator winding and fully linked amortisseur winding.

Subtransient Reactance: 12 percent, maximum.

H.12.2.7 Engine-Generator Set Control

The generator set shall be provided with a microprocessor-based control system, which is designed to provide automatic starting, monitoring, and control functions for the generator set. The control system shall also be designed to allow local monitoring and control of the generator set, and remote control as described in this specification. The control shall be mounted on the generator set. The control shall be vibration isolated and prototype tested to verify the durability of all components in the system under the vibration conditions encountered. The control shall be UL508 labeled, and meet IEC8528 part 4. All switches, lamps and meters shall be oil-tight and dust-tight, and the enclosure door shall be gasketed. There shall be no exposed points in the control (with the door open) that operate in excess of 50 volts. The controls shall meet or exceed the requirements of IEC Std 801.2, 801.3., and 801.5 for susceptibility, conducted, and radiated electromagnetic emissions. The entire control shall be tested and meet the requirements of IEEE587 for voltage surge resistance. The generator set mounted control shall include the following features and functions:

Three position control switch labeled RUN/OFF/AUTO.

In the RUN position the generator set shall automatically start, and accelerate to rated speed and voltage. In the OFF position the generator set shall immediately stop, bypassing all time delays. In the AUTO position the generator set shall be ready to accept a signal from a remote device to start and accelerate to rated speed and voltage.

Red "mushroom-head" push-button EMERGENCY STOP switch.

Depressing the emergency stop switch shall cause the generator set to immediately shut down, and be locked out from automatic restarting.

Push-button RESET switch.

The RESET switch shall be used to clear a fault and allow restarting the generator set after it has shut down for any fault condition.

Push-button PANEL LAMP switch.

Depressing the panel lamp switch shall cause the entire panel to be lighted with DC control power. The panel lamps shall automatically be switched off 10 minutes after the switch is depressed, or after the switch is depressed a second time.

H.12.2.8 Generator Over current and Fault Protection

Generator Circuit Breaker: Molded-case, electronic-trip type, 100 percent rated; complying with UL489.

- Tripping characteristics: Adjustable long-time and short-time delay and instantaneous.
- Trip settings: Selected to coordinate with generator thermal damage curve.
- Shunt Trip: Connected to trip breaker when generator set is shut down by other protective devices.
- Mounting: Adjacent to or integrated with control and monitoring panel.

Generator Protector: Microprocessor-based unit shall continuously monitor current level in each phase of generator output, integrate generator heating effect over time, and predict when thermal damage of alternator will occur. When signaled by generator protector or other generator-set protective devices, a shunt-trip device in the generator disconnect switch shall open the switch to disconnect the generator from load circuits. Protector shall perform the following functions:

- Initiates a generator overload alarm when generator has operated at on overload equivalent to 110 percent of full-rated load for 60 seconds. Indication for this alarm is integrated with other generator-set malfunction alarms.
- Under single or three-phase fault conditions, regulates generator to 300 percent of rated full-load current for up to 10 seconds.
- As over current heating effect on the generator approaches the thermal damage point of the unit, protector switches the excitation system off, opens the generator disconnect device, and shuts down the generator set.
- Senses clearing of a fault by other over current devices and controls recovery of rated voltage to avoid overshoot.

Ground- Fault Indication: Comply with NFPA 70, "Emergency System" signals for ground -fault. Integrate ground-fault alarm indication with other generator-set alarm indications.

H.12.2.9 Generator Set AC Output Metering

The generator set shall be provided with a metering set with the following features and functions:

2.5-inch, 90 degree scale analog voltmeter, ammeter, frequency meter, and kilowatt (KW) meter. These meters shall be provided with a phase select switch and an indicating lamp for upper and lower scale on the meters. Ammeter and KW meter scales shall be color coded in the following fashion: readings from 0-90% of generator set rating: green; readings from 90-100% of rating: amber; readings in excess of 100%: red.

Digital metering set, 0.5% accuracy, to indicate generator RMS voltage and current, frequency, output current, output KW, KW-hours, and power factor. Generator output voltage shall be available in line-to-line and line-to-neutral voltages, and shall display all three phase voltages (line to neutral or line to line) simultaneously.

H.12.2.10 Generator Set Alarm and Status Message Display

The generator set shall be provided with alarm and status indicating lamps to indicate non-automatic generator status, and existing alarm and shutdown conditions. The lamps shall be high-intensity LED type. The lamp condition shall be clearly apparent under bright room lighting conditions. The generator set control shall indicate the existence of the following alarm and shutdown conditions on a digital display panel:

- Low oil pressure (alarm)
- Low oil pressure (shutdown)
- Oil pressure sender failure (alarm)
- Low coolant temperature (alarm)
- High coolant temperature (alarm)
- High coolant temperature (shutdown)
- Engine temperature sender failure (alarm)
- Low coolant level (alarm or shutdown-selectable)
- Fail to crank (shutdown)
- Overcrank (shutdown)
- Overspeed (shutdown)
- Low DC voltage (alarm)
- High DC voltage (alarm)
- Weak battery (alarm)
- Low fuel-day tank (alarm)
- high AC voltage (shutdown)
- Low AC voltage (shutdown)
- Under frequency (shutdown)
- Over current (warning)
- Over current (shutdown)
- Short circuit (shutdown)
- Ground fault (alarm)
- Over load (alarm)
- Emergency stop (shutdown)

In addition, provisions shall be made for indication of two customer-specified alarm or shutdown conditions. Labeling of the customer-specified alarm or shutdown conditions shall be of the same type and quality as the above specified conditions. The non-automatic indicating lamp shall be red, and shall flash to indicate that the generator set is not able to automatically respond to a command to start from a remote location.

H.12.2.11 Engine Status Monitoring

The following information shall be available from a digital status panel on the generator set control:

- Engine oil pressure (psi or kPA)
- Engine coolant temperature (degrees F or C; Both left and right bank temperature shall be indicated on V-block engines.)

- Engine oil temperature (degrees F or C)
- Engine speed (rpm)
- Number of hours of operation (hours)
- Number of start attempts
- Battery voltage (DC volts)

H.12.2.12 Cranking And Governor

The control system provided shall include a cycle cranking system, which allows for user selected crank time, rest time, and No. of cycles. Initial settings shall be for 3 cranking periods of 15 seconds each, with 15 second rest period between cranking periods.

The control system shall include an idle mode control, which allows the engine to run in idle mode in the RUN poonly. In this mode, the alternator excitation system shall be disabled.

The control system shall include an engine governor control, which functions to provide steady state frequency regulation as noted elsewhere in this specification. The governor control shall include adjustments for gain, damping, and a ramping function to control engine speed and limit exhaust smoke while the unit is starting. The governor control shall be suitable for use in paralleling applications without component changes.

The control system shall include time delay start (adjustable 0-300 seconds) and time delay stop (adjustable 0-600 seconds) functions.

The control system shall include sender failure monitoring logic for speed sensing, oil pressure, and engine temperature which is capable of discriminating between failed sender or wiring components, and an actual failure conditions.

H.12.2.13 Alternator Control and Voltage Regulation Functions

The generator set shall include an automatic voltage regulation system which is matched and prototype tested with the governing system provided. It shall be immune from misoperation due to load-induced voltage waveform distortion and provide a pulse width modulated output to the alternator exciter. The voltage regulation system shall be equipped with three-phase RMS sensing and shall control buildup of AC generator voltage to provide a linear rise and limit overshoot. The system shall include a torque-matching characteristic, which shall reduce output voltage in proportion to frequency below a threshold of [48-49] HZ. The voltage regulator shall include adjustments for gain, damping, and frequency roll-off. Adjustments shall be broad range, and made via digital raise-lower switches, with an alpha-numeric LED readout to indicate setting level.

The voltage regulation system shall include provisions for reactive load sharing and electronic voltage matching for paralleling applications. Motorized voltage adjust pot is not acceptable for voltage matching.

Controls shall be provided to monitor the output current of the generator set and initiate an alarm when load current exceeds 110% of the rated current of the generator set on any phase for more than 60 seconds. The controls shall shut down and lock out the generator set when output current level approaches the thermal damage point of the alternator.

Controls shall be provided to monitor the KW load on the generator set, and initiate an alarm condition when total load on the generator set exceeds the generator set rating for in excess of 5 seconds.

Controls shall include a load shed control, to operate a set of dry contacts (for use in shedding customer load devices) when the generator set is overloaded .

An AC over/under voltage monitoring system which responds only to true RMS voltage conditions shall be provided. The system shall initiate shutdown of the generator set when alternator output voltage exceeds 110% of the operator-set

voltage level for more than 10 seconds, or with no intentional delay when voltage exceeds 130%. Under voltage shutdown shall occur when the output voltage of the alternator is less than 85% for more than 10 seconds.

A battery monitoring system shall be provided which initiates alarms when the DC control and starting voltage is less than 25VDC or more than 32 VDC. During engine starting, the low voltage limit shall be disabled, and if DC voltage drops to less than 14.4 volts for more than two seconds a "weak battery" alarm shall be initiated.

The control system shall include a ground fault monitoring relay. The relay shall be adjustable from 100-1200 amps, and include adjustable time delay of 0-1.0 seconds. The relay shall be for indication only, and not trip or shut down the generator set. Note bonding and grounding requirements for the generator set, and provide relay which will function correctly in system as installed.

H.12.2.14 Interfaces for Remote Monitoring

All control and interconnection points from the generator set to remote components shall be brought to a separate connection box. No field connections shall be made in the control enclosure or in the AC power output enclosure. Provide the following features in the control system:

Form "C" dry common alarm contact set rated 2A @ 30VDC to indicate existence of any alarm or shutdown condition on the generator set.

One set of contacts rated 2A @ 30VDC to indicate generator set is ready to load. The contacts shall operate when voltage and frequency are greater than 90% of rated condition.

A fused 10 amp switched 24VDC power supply circuit shall be provided for customer use. DC power shall be available from this circuit whenever the generator set is running.

A fused 20 amp 24VDC power supply circuit shall be provided for customer use. DC power shall be available from this circuit at all times from the engine starting/control batteries.

The control shall be provided with provisions for connection of remote monitoring equipment as described herein or shown on the Contractor's approved shop drawings.

H.12.2.15 Base

The engine-generator set shall be mounted on a heavy-duty steel base to maintain alignment between components. The base shall incorporate a battery tray with hold-down clamps within the rails.

Vibration isolators, spring/pad type, quantity as recommended by the generator set manufacturer.

Base frame shall have for lifting points.

The generator set shall be vibrationally isolated from structure on spring type antivibration mountings. There shall be no rigid connections between the generator set and the structure.

The spring type vibration isolators shall preferably be constructed from suitably treated and finished steel or steel alloys. They shall be manufactured with elastomeric acoustic pads to prevent transmission of high frequencies.

Spring type isolators shall have auxiliary dampers or adjustable snubber type restraints to prevent excessive movements as the machine speed passes through resonant frequency of the mounting system.

H.12.2.16 Vibration Isolation Devices

Characteristics of Elastomeric pads and spring isolators shall be:

Elastomeric Isolator Pads: Oil -and water- resistant elastomer or natural rubber, arranged in single or multiple layers, molded with a nonslip pattern and galvanized-steel base plates of sufficient stiffness for uniform loading over pad areas, and factory cut to sizes that match requirements of supported equipment.

- Material: Standard neoprene
- Durometer Rating: 50
- Number of Layers: Four

Restrained Spring Isolators: Freestanding steel, open-spring isolators with seismic restraint.

- Housing: Steel with resilient vertical-limit stops to prevent spring extension due to wind loads or if weight is removed; factory-drilled base plate bonded to ¼-inch-(6mm) thick, elastomeric isolator pad attached to baseplate underside; and adjustable equipment mounting and leveling bolt that acts as blocking during installation.
- Outside Spring Diameter: Not less than 80 percent of compressed height of the spring at rated load.
- Minimum Additional Travel: 50 percent of required deflection at rated load.
- Lateral Stiffness: More than 80 percent of rated vertical stiffness.
- Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.

H.12.2.17 Batteries and Chargers

Starting and Control Batteries: Starting battery bank, lead calcium type, 24 volt DC, sized as recommended by the generator set manufacturer, shall be supplied for each generator set with battery cables and connectors.

Battery Charger: A UL listed/CSA certified 10 amp voltage regulated battery charger shall be provided for each engine-generator set. The charger may be located in an automatic transfer switch, or may be wall mounted, at the discretion of the installer. Input AC voltage and DC output voltage shall be as required. Chargers shall be equipped with float, taper and equalize charge settings. Operational monitors shall provide visual output along with individual form C contacts rated at 4 amps, 120 VAC, 30VDC for remote indication of:

- Loss of AC power - red light
- Low battery voltage - red light
- High battery voltage - red light
- Power ON - green light (no relay contact)

Analog DC voltmeter and ammeter, 12 hour equalize charge timer, AC and DC fuses shall also be provided on the charger.

Batteries Technical Characteristics:

- Components: Sized so they will not be damaged during a full-cranking cycle with ambient temperature at maximum specified in Part 1 “Project Conditions” Article.
- Cranking Motor: Heavy-duty unit that automatically engages and releases from engine flywheel without binding.
- Cranking Cycle: (as required by NFPA 110 for system level specified).
- Battery: Adequate capacity within ambient temperature range specified in Part 1 “Project Conditions” Article to provide specified cranking cycle at least three times without recharging.
- Battery Cable: size as recommended by engine manufacturer for cable length indicated. Include required interconnecting conductors and connection accessories.

- Battery Compartment: Factory fabricated of metal with acid-resistant finish and thermal insulation. Thermostatically controlled heater shall be arranged to maintain battery above 10 deg C regardless of external ambient temperature. Include accessories required to support and fastener batteries in place.
- Battery-Charging Alternator: Factory mounted on engine with solid-state voltage regulation and 35-A minimum continuous rating.

Charger Technical Characteristics: Battery Charger: Current-limiting, automatic-equalizing and float-charging type. Unit shall comply with UL1236 and include the following features:

- Operation: Equalizing-charging rate of 10A shall be initiated automatically after battery has lost charge until an adjustable equalizing voltage is achieved at battery terminals. Unit shall then be automatically switched to a lower float-charging mode and shall continue to operate in that mode until battery is discharged again.
- Automatic Temperature Compensation: Adjust float and equalize voltages for variations in ambient temperature from minus 40 deg C to plus 50 deg C to prevent overcharging at high temperatures and undercharging at low temperatures.
- Automatic Voltage Regulation: Maintain constant output voltage regardless of input voltage variations up to plus or minus 10 percent.
- Ammeter and Voltmeter: Flush mounted indoor. Meters shall indicate charging rates.
- Safety Functions: Sense abnormally low battery voltage and close contacts providing low battery voltage indication on control and monitoring panel. Sense high battery voltage and loss of ac input or dc output of battery charger. Either condition shall close contacts that provide a battery-charger malfunction indication at system control and monitoring panel.
- Enclosure and Mounting: NEMA 250, type 1, wall-mounted cabinet.

H.12.2.18 Coupling System

The coupling system shall be of unit construction which forms the engine and generator into one unit of exceptional strength and ensures perfect alignment.

The alternator end shield and the engine flywheel housing faces shall be fully machined with spigots concentric to their shafts. The machined flanges mounted on the alternator shall be connected to the flywheel housing flange by steel bolts.

A flexible rubber block coupling shall be fitted between the engine and alternator to provide the drive and absorb the transmission of shock loads. The torsional flexibility shall be designed to match the torsional characteristics of the system to prevent resonant conditions.

H.12.2.19 Remote Annunciator

Provide and install a 20-light LED remote alarm annunciator with horn, located as shown on the Contractor's approved shop drawings or in a location which can be conveniently monitored by facility personnel. The remote annunciator shall provide all the audible and visual alarms called for by NFPA Standard 110 for level 1 systems; and in addition shall provide indications for high battery voltage, low battery voltage, loss of normal power to the charger. Spare lamps shall be provided to allow future addition of other alarm and status functions to the annunciator. Provisions for labeling of the annunciator in a fashion consistent with the specified functions shall be provided. Alarm silence and lamp test switch(es) shall be provided. LED lamps shall be replaceable, and indicating lamp color shall be capable of changes needed for specific application requirements. Alarm horn shall be switchable for all annunciation points. Alarm horn (when switched on) shall sound for first fault, and all subsequent faults, regardless of whether first fault has been cleared, in compliance with NFPA110 3-5.6.2.

H.12.2.20 Exhaust muffler(s) & Combined Soot Filter Catalytic Converter

Shall be provided for each engine, size and type as recommended by the generator set manufacturer. The mufflers shall be residential grade. Exhaust system shall be installed according to the generator set manufacturers recommendations and applicable codes and standards. Exhaust pipe shall have sufficient size to ensure that exhaust back pressure does not exceed the maximum limitations set by supplier the muffler and indoor exhaust piping shall be lagged to maintain a surface temperature not to exceed GSC. The insulation shall be installed so that it does not interface with the functioning of flexible exhaust fitting.

Flexible gastight connection pieces shall be provided in the exhaust pipe line to allow for thermal expansion and to prevent vibration being transmitted to the engine.

A clearance hole shall be allowed where exhaust pipe passes through a wall to avoid over heating.

H.12.2.21 Stainless Steel Double Skin Exhaust Pipes

Furnish and install where indicated on the Contractor's approved shop drawings a factory-built Underwriters Laboratories, Inc. listed chimney and breaching.

The chimney shall be listed by UL as a "1400" Fahrenheit Chimney" for continuous operation at 1400 °F and intermittent operation at 1800 °F and also as a "Building Heating Appliance Chimney" (UL103) for continuous operation at 1000 °F and intermittent operation at 1400 °F. The chimney manufacturer shall furnish all items which form a part of the assembly including straight sections, tee sections, elbows, cleanouts, drains, expansion joints, boiler adapter kits, guybands, flashing, counter flashing and insulated thimble where required.

Installation shall be made in accordance with the Manufacturer's recommendation and in compliance with the Underwriters Laboratory, Inc. listing. Product shall be listed for 4" clearance to combustibles. All chimney sections shall be of double wall construction with 4" insulation between the liner and the shell. The liner shall be 20 gage 304 stainless steel and the shell shall be of 24 gage aluminized steel for all sizes up to and including 36" I.D. for sizes 38" I.D. and above liner shall be 18 gauge 304 stainless steel and the shell shall be 20 gage aluminized steel. (Type 316 stainless steel is also available for liners and shells).

All section shall be joined with a Vee band sealed with silicone sealant around the inner liner and a drawband around the outer shell. Silicone sealant shall also be used on the outer drawband for exterior installations. High temperature joint cement shall be used instead of silicone sealant on the Vee band for operating temperatures exceeding 600 °F. Diameter and total stack height shall be as indicated on drawings. Chimney to terminate three feet above the roof. Free-standing chimney specifications

The Chimney shall be a metal jacketed refractory lined factory-built sectional type chimney. The sections shall be up to 40 feet in length and cylindrical in shape. It shall be freestanding, self-supporting and shall be designed to resist wind and earthquake loads. Drawings shall be prepared showing all features of the work including thickness of steel shell and refractory, overall height and diameter, and the design of the anchor system and foundation if required. The stack shall be mounted on a concrete foundation, which includes a drain, and is installed by a general contractor. Detailed design calculations for tension, compression, cantilever, vibration ovaling, dynamic stability and seismic forces shall be furnished. Wind forces are to be calculated as directed by the Engineer.. Deflection shall in no case exceed a ratio of 1 to 200 in reference to stack height.

The cast insulating acid resistant refractory shall be suitable for continuous operation at 1800 °F and for intermittent operation at 2000 °F as proven by Underwriter's Laboratories Standard #959. Each factory -built refractory section shall be up to 40'0" in length with internal angle-shelves to prevent ovaling. Assembly in the field shall be made by joining

sections with high temperature, acid resistant joint cement prior to welding the sections. All field welding shall be done by certified welders.

All exterior surfaces of the chimney shall be thoroughly cleaned of all rust, scale, dirt, grease, oil and other foreign matter in accordance with the latest revision of the Steel Structures Painting Council Surface Preparation Specification. Commercial Sandblast Cleaning using a compressed air blast nozzle and dry sand of maximum particle size no larger than that passing through a 16 mesh screen U.S. SIC-C series. All blast cleaned surfaces shall be painted the same day they are cleaned. No blast cleaned surface shall remain unpainted overnight. Shop painting shall consist of a prime coat of high temperature primer suitable for the application.

The chimney shall be secured to the foundation with plumbness not to exceed 1 – per 50 feet. Grouting of the chimney base plate shall be by the chimney erector or the general contractor.

Shop drawings will contain details as to thickness of outer shell and complete information on all chimney accessories. Calculations shall account for all stresses characteristic to that stack installation. The engineer's review shall not constitute checking or approval and shall in no way relieve the stack manufacturer of his full responsibility for the accuracy of the calculations and the ultimate safety and structural integrity of the stack. The stack and breaching shall fully conform to overall dimensions and characteristics as shown on the Contractor's approved shop drawings.

Accessories Ail pollution control test ports, gas sampling platforms, ladders, lightning protection, painters trolley shall be shown on shop drawings. Lightning protection will be designed to meet the standards contained in and published by the National Fire Protection Association. Grounding shall be accomplished by providing pads at the stack base for attachment of grounding cables (Per NFPA 780(1977) 3- 11.8 "Chimneys" and 5 - 11 "Metal Stacks") Grounding system to be installed under the electrical section of this specifications.

A base anchorage system shall be provided at the base of the chimney to transmit the forces in the shell to the foundation either directly or through the anchor bolts, without inducing local stresses of appreciable magnitude in the shell or exceeding the allowable bearing stress of the concrete.

General The outer steel jacket of the chimney shall be designed to resist the stresses resulting from the weight of the chimney, the effect of wind and earthquake, and to resist corrosion from the weather. The inner liner of refractory is designed to resist corrosion and temperature associated with the flue gases and absorb and dampen the effects of aerodynamic wind forces.

All surfaces to be welded shall be smooth, uniform, free of laminations, scale, grease, or other material which might adversely affect the welding. Precautions shall be taken to minimize distortion and stresses due to heat build-up. The stack manufacturer shall have developed weld-procedures which, in conjunction with the overall fabrication methods, will produce a stack that meets the quality requirements of these specifications. The detailed design shall take into consideration shipping procedures and adequately provide for any stresses which might normally develop there from. The allowable unit stresses for structural shapes shall be as given in the American Institute of Steel Construction Specification for Design, Fabrication and Erection of Structural Steel of Buildings.

Anchor bolts shall be set by a wood or metal template and plumbed in two directions true and level to the foundation by the contractor.

The chimney erector shall use special care in unloading and handling all materials from truck and/or cars. The erector shall handle all materials in such a way as to minimize damage and to avoid scarring or damaging the outer jacket or the refractory liner. If temporary erection clips or braces are employed, care should be used to prevent unsightliness upon removal. Tack welds should be ground smooth and holes shall be filled with weld metal and ground smooth. All finish welds are to be clean, showing good fusion and 100% penetration with extensive visual inspection.

If finish painting is required and after all exterior surfaces of the chimney are cleaned and free of all rust, dirt, grease, oil and other foreign matter. It shall be finish painted with two coats of finish paint. This finish painting shall be performed by the chimney erector.

Approved Manufacturers

- Selkirk
- Van Packer
- Flux Tubi

or approved equal

H.12.2.22 Acoustic Panels

Factory fabricated acoustic panel, double skin 0.5mm thick galvanized outer and inner sheets, a “Penta Post” supporting frame. Panels and frames are to be secured using internally bolted fixings so that welding minimized and integrity of the galvanized finish is maintained. Panels are to be provided with 25 mm thick fiberglass filter and to be designed to withstand an internal positive pressure of 250 mm water gauge in the outlet section and an internal negative pressure of 75 mm water gauge in the fan inlet section. Casing to be fitted with rails for mounting the unit components and all sections requiring servicing are to be fitted with quick release doors. All panels are to be screwed on external side to permit removal of components through either side of unit. Casing to be self supporting on 3m horizontal span or 3.6m vertical span.

H.12.2.23 Generator Mounted Power Command for Synchronizing

The digital power command shall consist of a control panel individually floor mounted with built-in microprocessor and shall also consist of:

Digital governing, voltage regulation, synchronization and load sharing controls, including export/ impact controls for paralleling with a mains bus.

Protection for alternator. (over current types).

Analog and digital AC output metering.

Battery monitoring system to sense and warn against a weak battery condition.

Digital alarm and status message display.

Display status of all critical engine and alternator generator set functions.

Smart starting control system with integrated fuel ramping to limit black smoke and frequency overshoot in addition to cold weather starting.

Network capability.

Dust, water + oil resistant enclosure

Semi automatic paralleling facilities including single check synchronizer, auto-close attachment for circuit breaker, common busbar and synchroscope to adjust speed of incoming generating set(s).

H.12.2.24 Master Control Cubicle

A. Shall contain all system-totalizing controls for the integrated system operation as specified below:

1. Bus Metering:

- AC ammeter.
- AC voltmeter.
- Frequency meter 55-65 Hz Scale.
- Watt/Var meter.
- Ammeter/Voltmeter phase selector switches with current and potential transformers and proper fuses.
- f. All necessary control hardware for interfacing with SCADA / BMS system

2 . Reverse Power Monitors: Solid-state reverse power monitors shall be furnished to sense motorizing of a failing engine-generator set. Upon detection of a reverse power flow, the monitor shall signal the alarm circuit for immediate power disconnect of the generator and actuation of load dumping circuits, and energize the audible and visual alarm signals. Monitors shall automatically reset the open generator disconnect from the bus. An induction disc type reverse power relay with equivalent performance may be submitted for approval. The monitor shall have the following features:

- Accurate operation at power factors down to 0.2 lagging or leading.
- Minimum 10 A output contacts rated at 480 V.
- Circuitry arranged to continually sense the output power of the generator for magnitude and direction.
- Operate accurately over voltage range of 70% to 110% of rated voltage.
- Adjustable dial for trip power range.
- Test switch to simulate reverse power for periodic testing. Switch shall be arranged to cause sensing circuitry to measure reverse power.

3. Synchroscope:

- Furnish with a selector switch and manual means of paralleling engine-generator sets for override of the automatic system.
- Furnish with a synchronizing phase band limiter to sense and compare the phase angle difference in the generators, which are to be manually paralleled, and lock out the manual paralleling button unless within 15 degrees (electrical) of synchronism.

4. Load Demand Monitor: A load demand monitor shall sense the load connected to the bus, and establish the proper number of engine- generators to operate and maintain the connected load with a minimum on-line reserve generating capacity of 10% of the rating of a single engine-generator. The load monitor shall also disconnect a generator from the bus whenever the on-line reserve capacity exceeds 110% of a single generator set. The load demand monitor shall be adjustable to initiate the addition and removal of a generator from the main bus. The load monitor shall maximize fuel economy while maintaining sufficient capacity to sustain the load.

5. Frequency Monitor; A frequency monitor with integral time delay shall initiate load dumping upon a reduction of the bus frequency to 58 Hz or less for a period of two seconds or more. Upon sensing a bus under-frequency, the system shall automatically shed the lowest priority load connected. This shed circuit shall override any manual load add activity and lock out the manual load add circuitry. Visual and audible alarms shall be energized upon sensing of bus under-frequency load dump.

6. Alarms: Provide individual visual signals plus a common audible alarm and silencing circuitry. Provide a test switch which will momentarily actuate the visual and audible alarms. The following conditions shall be monitored:

- Low Fuel Level Main Storage Tank shall be energized when the fuel oil level decreases to less than one-third of total capacity.
- Under-frequency failure.
- Controls not in automatic mode.
- Load shed circuit activation.

B. Control Logic:	
	The control logic shall be distributed between the Master Control Cubicle and each Engine-Generator Control
	Cubicle such that each engine-generator is capable of starting and paralleling to the bus in the event of receipt of a
	start signal and failure of the Master Control Cubicle.
C. Control Power:	
	Control power for the paralleling controls shall be derived from battery supply as specified in Section, MEDIUM-
	VOLTAGE SWITCHGEAR.

H.12.2.25 Engine-Generator Control Cubicle

Starting and Stopping Controls:

- A three-position, maintained-contact type selector switch with positions marked "AUTOMATIC," "OFF," and "MANUAL". Provide flashing amber light for the OFF and MANUAL positions.
- A momentary contact push-button switch with positions marked "MANUAL START" and "MANUAL STOP."
- Selector switch in AUTOMATIC position shall cause the engine to start automatically when a single pole contact in a remote device closes. When the generator's output voltage increases to not less than 90% of its rated voltage, and its frequency increases to not less than 58 Hz, the remote devices shall transfer the load to the generator. An adjustable time delay relay, 0 to 15 minute range, shall cause the engine-generator to continue operating without any load after completion of the period of operation with load. Upon completion of the additional 0 to 15 minute (adjustable) period, the engine-generator shall stop.
- Selector switch in OFF position shall prevent the engine from starting either automatically or manually. Selector switch in MANUAL position shall cause the engine to start when the manual start pushbutton is depressed momentarily.
- With selector switch in MANUAL position, depressing the MANUAL STOP push-button momentarily shall stop the engine after a cool down period.
- A maintained contact, red mushroom-head push-button switch marked "EMERGENCY STOP" will cause the engine to stop without a cool down period, independent of the position of the selector switch.

Engine Cranking Controls:

- The cranking cycles shall be controlled by timer that will be independent of the battery voltage fluctuations.
- The cranking controls shall crank the engine through one complete cranking cycle, consisting of four starting attempts of 10 seconds each with 10 seconds between each attempt.
- Total actual cranking time for the complete cranking cycle shall be 40 seconds during a 70-second interval.
- Cranking shall terminate when the engine starts so that the starting system will not be damaged. Termination of the cranking shall be controlled by a self-contained, speed-sensitive switch. The switch shall prevent re-cranking of the engine until after the engine stops.

- After the engine has stopped, the cranking control shall reset.

Supervisory Controls:

- Overcrank: a. When the cranking control system completes one cranking cycle, four starting attempts without starting the engine, the OVERCRANK signal light and the audible alarm shall be energized. b. The cranking control system shall lock-out, requiring a manual reset.
- Coolant Temperature: a. When the temperature rises to the predetermined first stage level, the HIGH COOLANT TEMPERATURE - FIRST STAGE signal light and the audible alarm shall be energized. b. When the temperature rises to the predetermined second stage level, which shall be low enough to prevent any damage to the engine and high enough to avoid unnecessary engine shutdowns, the HIGH COOLANT TEMPERATURE - SECOND STAGE signal light and the audible alarm shall be energized and the engine shall stop. c. Difference between the first and second stage temperature settings shall be approximately 10° F [-12° C] . d. Permanently indicate the temperature settings near the associated signal light. e. When the coolant temperature drops below 70° F [21° C], the LOWCOOLANT TEMPERATURE signal light and the audible alarm shall be energized.
- Low Coolant Level: When the coolant level falls below the minimum level recommended by the manufacturer, the LOW COOLANT LEVEL signal light and audible alarm shall be energized.
- Lubricating Oil Pressure: a. When the pressure falls to the predetermined first stage level, the OIL PRESSURE - FIRST STAGE signal light and the audible alarm shall be energized. b. When the pressure falls to the predetermined second stage level, which shall be high enough to prevent damage to the engine and low enough to avoid unnecessary engine shutdowns, the OIL PRESSURE - SECOND STAGE signal light and the audible alarm shall be energized and the engine shall stop. c. The difference between the first and second stage pressure settings shall be approximately 15% of the oil pressure. d. Permanently indicate the pressure settings near the associated signal light.
- Overspeed: a. When the engine RPM exceeds the maximum RPM recommended by the manufacturer of the engine, the engine shall stop. b. Simultaneously, the OVERSPEED signal light and the audible alarm shall be energized.
- Low Fuel Level - Day Tank:

When the fuel oil level in the day tank decreases to less than the level at which the fuel oil transfer pump starts to refill the tank, the LOW FUEL DAY TANK light and the audible alarm shall be energized.

- Low Fuel Level - Main Storage Tank:

When the fuel oil level in the storage tank decreases to less than one-third of total tank capacity, the LOW FUEL- MAIN STORAGE TANK signal light and audible alarm shall be energized.

- Reset Alarms and Signals:

Overcrank, Coolant Temperature, Coolant Level, Oil Pressure, Overspeed, and Low Fuel signal lights and the associated audible alarms shall require manual reset. A momentary-contact silencing switch and push-button shall silence the audible alarm by using relays of solid state devices to seal in the audible alarm in the de-energized condition. Elimination of the alarm condition shall automatically release the sealed-in circuit for the audible alarm so that it will be automatically energized again when the next alarm condition occurs. The signal lights shall require manual reset after elimination of the condition which caused them to be energized.

Install the audible alarm just outside the generator room in a location as directed by the CLIENT. The audible alarm shall be rated for 85 dB at 10 ft [3 M].

- Generator Breaker Signal Light: a. A flashing green light shall be energized when the generator circuit breaker is in the OPEN or TRIPPED position. b. Simultaneously, the audible alarm shall be energized.

Monitoring Devices:

- Electric type gauges for the cooling water temperatures and lubricating oil pressures. These gauges may be engine- mounted with proper vibration isolation.
- A running time indicator, totaling not fewer than 9,999 hours, heavy duty, and an electric-type tachometer.
- Voltmeter, ammeter, frequency meter, kilowatt meter, manual adjusting knob for the output voltage, and the other items shown on the Contractor's approved shop drawings shall be mounted on the front of the generator control panels.
- Install potential and current transformers as required.
- Individual signal lights: a. OVER-CRANK b. HIGH COOLANT TEMPERATURE - FIRST STAGE c. HIGH COOLANT TEMPERATURE - SECOND STAGE d. LOW COOLANT TEMPERATURE e. OIL PRESSURE - FIRST STAGE f. OIL PRESSURE - SECOND STAGE g. LOW COOLANT LEVEL h. GENERATOR BREAKER i. OVERSPEED j. LOW FUEL LEVEL - DAY TANK k. LOW FUEL LEVEL - MAIN STORAGE TANK

l. All necessary control hardware for interfacing and reporting all alarms and measurements listed in this section to SCADA / BMS

- Lamp Test: The Lamp Test momentary contact switch shall momentarily actuate the alarm buzzer and all the indicating lamps.

Automatic Voltage Regulator:

- Shall correct voltage fluctuations rapidly and restore the output voltage to the predetermined level with a minimum amount of hunting.
- Shall include voltage level rheostat located inside the control cubicle.
- Provide a 3-phase automatic voltage regulator immune to waveform distortion.

H.12.2.26 Paralleling Operation

Emergency (automatic) Mode:

- Upon initiation of the automatic sequence (loss of utilities)/ all engine-generators shall start. The first engine-generator to achieve 90% of nominal voltage and frequency shall be connected to the emergency bus to restore power to the providing power to essential electrical systems throughout the project.
- When the remaining engine-generator starts, the generator paralleling controller automatically parallels the generator to the emergency bus, providing required capacity.
- With all generators running and utility power still not restored, pick up normal bus loads to go into power mode as per SCADA / BMS system controls.
- Load demand sensing shall be furnished to ensure that sufficient generating capacity is connected to the bus to carry the load, and that the load carried is sufficiently large to sufficiently load the generators (30% or greater).
- Should the load on the generators fall to 30% while more than generators are operating, 1 generator will be taken off line and cooled down.
- Should a single generator be carrying all loads and load on that generator increase to greater than 80% continuously (30 minutes or more) or greater than 100% other than a brief load transient, or immediately should

the load on the running generator approach 110%, start a second generator if not already running and parallel to the bus to share load.

- Should the load on the running generator or generators increase to greater than 110% of capacity, load will be shed by immediately through SCADA /BMS system to protect emergency loads.
- Load demand sensing shall ensure that the online reserve capacity does not fall to less than 10% or exceed more than 110% of a single engine-generator. Upon sensing if the connected load exceeds the preset limit for an established period of time, the idle engine generator will be started and paralleled. If upon sensing the connected load is determined to be less than the preset limit for an established period of time, the last engine-generator will be ready for next operation.

Restoration to Normal

Utility power:

When the utility can reliably carry the normal loads, transfer the emergency bus to the utility as follows:

- Open any closed generator breakers, dropping the emergency bus.
- Immediately restore the emergency bus from the normal bus by closing a selected feeder tie
- Cool down the generators by running them unloaded for an adjustable period of time up to 15 minutes maximum, and then shut down. All controls associated with operation of the engine-generator shall automatically reset for the next automatic operation.

Manual Mode:

- Operate engine-generators manually for test purposes from either of the master control consoles. The console shall have a loss of normal power simulation switch / button which simulates loss of both utilities, causing the emergency system to start up and take on full project load as described above.
- The console shall also allow the authorized operator to reconfigure the power system by selecting the desired mode of operation at the console. The system controller shall be capable of transferring the platform from one programmed mode to another between any of the 16 programmed modes of operation as specified on the Contractor's approved shop drawings.
- Switchgear protective interlocks shall be provided to allow configuring the switchboard manually without danger of inadvertently paralleling sources.

Exercising Mode:

- Controls shall allow simulated automatic and manual testing of each engine-generators.
- Utility Peak Demand Reduction Mode: as applicable if requested by Client)

The system shall include provisions for future addition of control equipment capable of operating the power system to reduce utility peak demand in the following way:

- Upon utility initiation of an automatic sequence for utility peak demand reduction operation, all engine-generators shall be started. When the first engine-generators achieves 90% of nominal voltage and frequency, the emergency bus shall be transferred off of normal power and to the generator. As the second engine-generators starts and achieves 90% of nominal voltage and frequency, their individual automatic synchronizers shall initiate control of voltage and frequency to bring the oncoming engine-generator into synchronism with the bus. Upon achieving synchronism the oncoming engine-generator shall be paralleled. With engine generators are paralleled, the system shall transfer the normal bus loads off the utility and onto the power system.

- The system shall prevent load transfer to the bus until there is sufficient capacity to carry full load. Provisions shall be included to manually override the load addition circuits for supervised operation.
- Upon termination of the utility peak demand reduction operation, the normal bus load shall be retransferred off emergency, to the normal power source. Then the emergency bus shall be transferred off the generators to the normal supply, the engine-generators shall be run for a cool down period, and shut down.

H.12.2.27 Technical Characteristics of Synchronizing System

Governing Performance:

- Frequency regulation: Isochronous under varying loads from no load to full load.
- Frequency drift: $\pm 0.5\%$ drift for a 60° F (33° C) change in ambient over eight (8) hours with temperature stabilization at each points.

Isochronous Real Load Sharing:

- Real load sharing controls allow generator sets to share load to within as low as 1% of equal. Load sharing controls operate directly on the engine governor actuator, to provide zero droop in frequency for loads from zero to 100% of rated generator set capacity.
- Kilowatt import and export control, to allow the generator set to share load with an infinite bus. The controls allow setting of ramping rate, and steady state operation level. Steady state KW level, or on a signal from a remote control device which allows loading of the generator set as a function of the load provided by the utility (mains) service.
- Load demand ramping controls cause the generator set to ramp down to a low load condition prior to switching off on a load demand signal. On removing the load demand signal, the generator set will automatically start, synchronize to the system bus, and close at no load. The generator set then ramps up to its proportional share of the total on the system.

Isochronous Reactive Load Sharing:

- Reactive load sharing controls allow generator sets to share load to within as low as 1% of equal. Load sharing controls operate directly on the excitation system, to provide zero droop in voltage for loads from zero to 100% of rated generator set capacity.
- Reactive load sharing controls allow generator set to share reactive load with an infinite bus. The control system allows a technician to adjust the operating reactive load level on the generator set.

Synchronizer:

- Range: The synchronizer can drive generator set frequency and voltage to a bus value which is -40% to $+10\%$ of selected voltage and frequency. Ramp speed for matching is 4% second.
- Frequency differential: Controls generator set to match bus frequency.
- Voltage differential: Electronically controls generator set voltage to within 1% of system bus voltage, and checks for correct phase rotation to bus.
- Permissive protection: Adjustable for a phase difference of 5-20 degrees, with phase difference decreasing. Time delay is adjustable from 0.5 to 5 seconds.
- Control system: Automatically resets bus frequency and voltage to preset values after the paralleling breaker closes.
- Includes "Dead Bus" sensor: Allows closure of the generator set to an inactive system bus.

The front panel of the control panel shall be formed by a single membrane that covers the entire control surface. The control face shall be easy to clean and impervious to water spray, dust and oil/exhaust residue. Electronic control switches for many functions shall be integral to the front panel. The control door shall be dual/ moisture and RFI/EMI gasket to protect internal components from airborne contaminants. The control shall perform properly over a wide range of environmental conditions and is vibration, RFI/EMI, and surge tested.

- Operating temperature: -40° C to +70° C.
- Storage temperature: -40° C to +85° C.
- Humidity: up to 95% relative, non-condensing.
- Altitude: up to 3048 M (10,000 feet) without derating.

H.12.2.28 Controls and Adjustments Switches

An oil tight, three position switch shall start and stop the generator set locally or shall enable start/stop control from a remote location. It shall provide the following functions:

- The “OFF” position de-energized all primary DC circuits. When the switch is in this position, the non-automatic indicator will flash continuously.
- The “RUN” position energized the control and initiates generator set starting operation.
- The breaker control switches are enabled only in the “RUN” position. The non -automatic indicator will flash when the switch is in the “RUN” position, indicating that the paralleling breaker will not automatically close.
- The “AUTO” position enables the control to receive a start signal from a remote location, such as an automatic transfer switch or master control panel.

A two position safety “mushroom” head switch shall provide an easy and obvious means to immediately shut down the generator set in the event of an emergency condition.

H.12.2.29 Master Digital Control Panel: (Individual Floor Mounted)

Provide a master control panel to monitor and control the operation of the entire paralleling system. The master control panel shall contain the components described in this section, and all meters, controls and status of the generators shown in the previous sections. Master digital command panel shall be located in generator room or in totalizer board, as per system vendor recommendation and as close as possible from alternator panel. The digital master control shall be microprocessor based paralleling system component, designed to directly interface with local power command paralleling. Power command paralleling systems shall utilize a true distributed logic design. Each major component in the system shall include sufficient controls and logic to operate completely autonomously in the event of failure of other system components. Reliability shall also be improved by extensive use of microprocessor based components and elimination of common nuisance failure points in the system, such as incandescent lamps. A touch screen shall be quoted as an alternative extra and if approved shall eliminate the need for switches and rotary potentiometers which are open the environment, and subject to failure due to contamination or degradation of contact assemblies. The use of a common set of hardware for almost all applications allows complete, standardized documentation to the system. Since the same core software, control and monitoring components are used in most applications, system reliability is not compromised by use of untested components or one-of-kind software.

The control system, including touch screen and the LED annunciator panel shall be designed for operation under the following conditions:

Operating temperature: 0 to + 60 degrees C. Storage temperature: -30 to + 70 degrees C. Humidity: up to 95% relative, non-condensing.

The control system shall be housed in a rigid, free-standing, metal enclosed structure designed to require front access only. Framework of the equipment is constructed of minimum 12 gauge (2.5 mm) steel sheet metal. The framework and all other sheet metal components of the system are primed with a rust-inhibiting primer and finished with satin finish ANSI 61 gray or black enamel.

Control components shall be totally isolated from power-carrying components by metal or insulating barriers. All components and surfaces operating at more than 50 volts are shielded to prevent inadvertent contact.

All control wiring is UL type 105 degree C, 600 volt rated and sized as required. Each wire, device and functional component shall be defined by silk-screen or similar permanent identification.

Fuses shall be installed in DIN-rail mounted safety- type fuse holders with integral “fuse blown” indicating lamps. Terminal blocks for all field connections shall be DIN-rail mounted devices with removable plugs for connection of section-to-section breaks. RMS AC metering transducers shall provide input via a serial link to the system PLC, so that AC metering data can be displayed on the system Touch screen. The transducers shall operate with a metering accuracy of plus or minus 0.25% for amps, volts, power and energy; and 0.01 hertz for frequency. The transducers shall meet IEEE/ANSI C 37.50 SWX ring wave test requirements and have a voltage breakdown level of in excess of 2500 volts.

Master Control Front Panel

The front panel of the master control shall contain the following instruments and devices.

- 1% accuracy True RMS digital instruments to monitor total output of bus: Ammeter, Voltmeter, Frequency Meter, Wattmeter, Varmeter, Power Factor Meter, kW-Hour Meter, kW demand, kVAR hours, kVA hours. Selector switches to allow viewing of voltage and amperes for each phase shall be provided. For 3-phase/4-wire systems the voltmeter shall indicate line to line and line to neutral conditions.
- Operator Interface Panel. An operator interface panel shall be provided which allows the operator to monitor and control the following functions:

General System Status: A graphic status panel shall be provided which indicates Generator set and bus configuration; genset designation and KW rating; generator set and bus energized/de-energized indication; generator set mode (auto/not in auto/run); generator set alarm status (normal/warning/shutdown); paralleling breaker designation and status (open/closed/tripped); utility main and feeder breaker status for breakers controlled by this system (see the Contractor's approved shop drawings for details of equipment required).

Load Demand On/Off control switch and indicating lights. The system shall also include provisions for field adjustment of load demand pickup/drop out set points, load demand shut down time delay, and load demand shut down sequence.

Load Shed On/Off control switch and indicating lights. (One set for each load shed level.)

Load Add control switches and indicating lights. (One set for each load shed level.)

Test On/Off control switch and indicating lights.

System Auto/Manual switch and indicating lights.

Individual generator set manual paralleling provisions (one set per generator set in the system), including: generator set start/stop switches which are operable only in the manual system mode(control switch on the generator paralleling control panel must be in the “auto” position); generator set synchronized indication; synchroscope; manual breaker control switches (open/closed).

Individual generator set fault reset (all but emergency stop).

Under Frequency/Over Load reset. The system shall include provisions for field adjustment of load shed time delay.

Help screens for each display screen, to describe the functions which can be performed and the meaning of the terms on each screen.

Emergency messages shall be provided to highlight operational problems in the system to the operator, and provide specific direction to the operator describing how to respond to the problem.

Solid State System Status Panel. The system status panel shall have the following features and functions:

- Alarm Silence Push-button Switch
- Alarm horn
- Indicating lamps to indicate the following conditions:
- Function Color Alarm Horn
- Load Demand Mode green
- Priority “n” Load On (1 lamp/level) green
- Load Shed Level “n” (1 lamp/level) red *
- System Test green
- Remote System Start red
- Check Generator Set (1 per generator set) red *
- Bus Overload red *
- Non-Automatic red * (flashing)
- Internal Control Components

The following internal controls shall be provided within the master control section:

- Programmable controller for interface with touch screen, and to provide load demand, load pick-up, and load shed functions.
- Load pick-up output contacts, rated 10 A at 600 VAC (3 contacts per level). There shall be a minimum of one level of output contacts for each generator set in the system.
- Load shed output contacts, rated 10 A at 600 VAC (3 contacts per level). There shall be a minimum of one level of output contacts for each generator set in the system.

Provide all other components required, such as properly sized current transformers, transducers, terminal blocks, etc., for reliable system operation.

H.12.2.30 System Operation

Automatic Operation: The normal mode of system operation shall provide for unattended automatic emergency paralleling of all engine generator sets, transfer of load, and load control for the entire emergency power system. Emergency power shall be supplied to the system emergency loads within 10 seconds after interruption of the normal service or in case of overvoltage or under voltage of the normal service. Upon receiving a signal of failure of normal power, the system control unit will signal all engine generators to start. Each engine generator will automatically start, and the first generator to achieve 90% of rated voltage and frequency will automatically connect to the emergency bus, via the generator circuit breaker and connexed step-up transformer. Generators with improper voltage or frequency shall not be permitted to connect to the bus until the abnormality is corrected. As the remaining generators achieve proper operating conditions, the automatic synchronizer of each generator control unit will rapidly force them into synchronism with the bus, by sending correction signals to the electronic governor of each engine generator. After proper synchronism is attained, each engine generator will be automatically shared between all generators connected to the bus.

The transfer of load from normal to emergency bus shall be controlled by the system controls and shall occur in accordance with an established load control program thru independent controller or combined with the centralized

monitoring and control system i.e. Building Management System (preference is for second alternative, and Contractor to deploy necessary action to ensure coordination and compatibility of hardwares for a perfect operation of the system as intended the BMS interfaces with all the motorized breakers of power distribution and contactors for load shedding shall be included in this part of contract). The program shall assign priority level to each load. The highest priority load shall be the first to transfer to the emergency bus, regardless of the number of load contractors experiencing the failure. The first load transfer shall occur only after adequate generating capacity is connected to the bus. As additional capacity is connected to the bus, subsequent load transfers will occur in order of their assigned priority levels, as established by the load control program. The number of load priority levels will never exceed the number of engine generator sets.

The load control shall, as required, automatically dump loads connected to the emergency bus, by controlling distribution circuit breakers within the distribution units. If a sustained bus under frequency occurs, or an engine generator has experienced a fault while all load transfer contactors are in the emergency position. The load control shall activate and exercise control over blocks of emergency fault, a block of load equal to the capacity of one generator shall be dumped. After the engine generator's fault condition has been corrected and manually reclosed to the emergency bus, the load can be reinstated.

In the event of a sustained bus under frequency, a block of load will be dumped approximately every 10 seconds (adjustable) until the bus regains proper frequency. Loads dumped in this manner shall be manually reinstated. Loads will be dumped and reinstated in accordance with their assigned priority level as established by the load control program. The lowest priority load will be dumped first and the highest priority load dumped last. It shall be possible to selectively disable the dump circuitry of the highest priority loads, to prevent dumping regardless of system conditions.

Once normal power has returned and been determined stable, the transfer switch loads connection contactors or breakers and load shedding contactors will signal a return to the normal source. After all loads have transferred load back to the normal source, the engine generators will run unloaded for a short cool down period (adjustable 0-15 minutes) and then shut down. The emergency power system circuitry shall then automatically reset and remain in readiness for the next failure of normal power.

Manual Operation: The emergency power system shall have the capability of being manually operated. Each generator set may be individually started by engine control switches located on the respective engine generator control units. Once started and stable, the generator may be manually connected to the emergency as through individual generator circuit breakers. After the emergency bus is energized by the first generator, each remaining generator may be connected to the bus by utilizing permissive paralleling circuitry. Each generator control unit will be equipped with a synchronizing switch, generator breaker control switch, engine speed adjusting potentiometer and a generator voltage adjust rheostat to facilitate manual paralleling. The master control unit shall include an integral synchronizing "swing" panel equipped with bus and on coming generator instrumentation, along with synchronizing lights to enable manual paralleling. During manual operation, all load dump circuitry shall be disabled by a load dump disable switch and individual distribution breaker control switches shall provide the means of controlling system loads.

A key operated system mode switch shall be provided to manually test the emergency power system. The switch shall have three positions: "full load test", "normal", "no load test", with the key removable in the "normal" position only. In the "normal" position the system shall be in readiness for fully automatic operation. The "no load test" position shall automatically start and parallel all generators sets to the emergency bus, however, load will not be transferred as long as normal power remains available. The "full load test" position shall automatically start and parallel all generator sets and transfer load to the emergency bus.

Electrical Components: To include all required meters, transformers, fuses, control relays, control wirings, timers, indicating lamps, switches etc.

H.12.2.31 Fuel Oil Storage

Base-Mounted Fuel Oil Tank: Factory installed and piped, complying with UL 142 fuel oil tank. Features include the following :

- Tank level indicator.
- Capacity: Fuel for eight hour's continuous operation at 100 percent rated power output.
- Vandal-resistant fill cap.
- Containment Provisions: Comply with requirements of authorities having jurisdiction.

Above Ground Storage (Vertical Mounting)

- Tank shall be constructed of not less than 6 mm. thick welded black steel sheet metal to the capacities indicated on Drawings, and in accordance with UL standard for steel above ground tanks for flammable and combustible liquids .UL. 142-1972.
- Tank shall be tested for leaks before installation and shall be painted with two coats of red lead oxide or approved equal, and two coats black bituminous paint , and finished with Silver or White enamel paint.
- Tank shall be mounted on a concrete pad and shall be equipped with the following: • Manhole and manhole cover 600 x 600 mm. • Protected oil level indicator fixed to the tank. (level gauge Cat and Mouse). • Fill and vent pipes. • Two gate valves one in fuel supply line and one in drain line. • Overflow, drain and supply lines. • One external and one internal caged ladders. • Earthing connection.

H.12.2.32 Miscellaneous Controls

- Under frequency Relay

A solid state under frequency relay shall be provided to monitor the frequency of the emergency bus for alarm and load dump.

- Mode Switch A key operated system mode switch shall be provided to enable testing the emergency power system. The switch shall have three positions, No load test, normal, and full load test, with the key removable only in the normal position.
- Load Dump Disable Switch Shall be provided to enable all load dump circuits to be disabled simultaneously. The switch shall be key operated having two positions. Normal and Disable, with the key removable only in the normal position.
- Best Battery Selector Solid state circuitry shall be supplied in the system control unit to automatically select the best set of engine starting batteries as the system control DC sou. The selected DC source shall supply all DC control logic within the system controls. If the selected source deteriorates the next best set of engine starting batteries shall automatically become the system control DC source.
- System Alarm Horn Of the solid state DC type shall be provided to audibly annunciate system abnormalities of bus under frequency and load dumps.
- Status and Fault Lamps A group of these lamps shall be provided for each distribution feeder circuit and the emergency system control. Lamps shall be provided as follows:

System status and/or fault lamps shall be provided, and shall illuminate to indicate the following conditions . • Full load test • No load test • Load dump disabled

Distribution feeder circuit status lamps shall illuminate to indicate the status of each transfer switch associated emergency distribution circuit breakers as follows: • Transfer switch and loads connection gears in normal. • Transfer switch and loads connection gears in emergency, load dumped.

- Alarm Silence Push Button And circuitry shall be provided to silence the system alarm horn prior to resetting a fault or to acknowledge a condition.
- Transformers Potential transformers shall be provided as required for bus metering and synchronizing circuits. Control transformers shall be provided as required to supply power to the distribution circuit breaker closing circuits.
- Pilot Lights Are to indicate which L.V. breaker is on.
- Instruments Are to include voltmeter and ammeter with selector switches.
- Circuit Breakers Used instead of contractors are to provide same functions as a minimum requirement and are to be electrically and manually operated non-automatic type.
- Wiring Moisture and heat resistant silicon rubber insulated stranded copper conductors, modularly and neatly arranged on master terminal blocks, with suitable numbering strips and appropriate cartridge type fuses where required. Flexible wiring is to be used on all hinged/draw-out components.
- Connections Are to be made at a front terminal block with no live metal exposed. Power cables are to terminate on fixed insulated copper connectors suitably sized to receive specified cables. Cable glands and gland plates are to be provided.
- Metal Cases Of instruments control switches, relays etc. are to be connected by flexible protective conductors, of not less than 2.5 mm² section, to nearest earthing bar or terminal.
- Earthing Earthing bar is to be provided for connection of protective earthing co, using set-screw or bolted anti-turn pressure terminations.
- Ferrules Wire ends are to be fitted with numbered ferrules of approved type at each termination.

If the bus does not return to proper frequency within a predetermined period of time, additional load shed signals will be generated.

S Y S T E M T E S T I N G :

Test Mode: Operation of the test switch on the paralleling control system master control panel shall simulate a power failure in the system, and the system shall function as described in "Loss of Normal Power" above.

The paralleling equipment shall be tested with the generator sets for this project at the factory, at rated load and power factor. At least 2 gensets at a time shall be tested with dummy loads. System testing shall include tests to demonstrate all functions of the system, and system cold start test, parallel unit load sharing, and transient loading of the system, at loads up to and including full block loading of the generator sets. These tests may be witnessed by the engineer. Provide certified factory test report documenting factory system testing. See generator set testing requirements for other test requirements.

H.12.2.33 Distributed Control and Monitoring Network

- On-site power system equipment shall be interconnected by a serial communications network for distributed control and monitoring of the complete system. All of the data listed in this section shall be accessible from the network. The network shall be capable of initiating testing the generator set(s) and transfer switch(es) (as applicable) and reporting alarms and status information.
- The network application devices shall be specifically designed for control and monitoring of generator sets, transfer switches, and accessory equipment of the power system as installed. The network application devices (hardware) and programming (software) shall be designed, manufactured, and supported by the same manufacturer.

- Network Protocol: The network protocol shall be Echelon Lonworks. The network protocol shall be peer-to-peer such that any network application device has access to the network at any time. Access to the network shall be managed effectively, including error detection, priority access for critical messages, and a collision resolution and avoidance scheme. Network devices shall be addressable such that the network is configurable using software, initially and for future modifications. Messages shall be capable of end-to-end acknowledgement. Token ring or master/slave protocols will not be accepted at submittal.
- Network Media: The network media shall be a minimum 78 kbps transformer-coupled twisted pair with a range of 2000 meters. The digital signal shall be Manchester encoded or alternate means to achieve wiring polarity insensitivity. The transformer coupled-twisted pair cable shall be unshielded meeting UL Level IV or EIA Cat 4 transmission characteristics as recommended by the manufacturer. The cable shall include as a minimum, one 22 AWG pair for data communications, and a second (spare) 22 AWG pair.
- Topology: The network topology shall be a multi-drop bus with end terminations as required. Drops, or stubs, shall be permitted at any point along the bus, each drop with a ten foot maximum distance from the bus.
- Network Power: The network shall function normally whether or not AC power is available in the facility.
- Network Monitor: The distributed control and monitoring network shall be capable of being monitored by an IBM- compatible personal computer, 486 minimum, running Microsoft Windows 3.1 or higher. The personal computer and its peripheral equipment is not included in the contract for the on-site network

Generator Set Monitoring: The network shall monitor real-time generator set operating data, alarms and status information. Alarm and status information to be date and time stamped, and automatically entered in the Events Log or Alarms Log as appropriate shall include the following:

Table: Generator Set Real Time Operating Data, Alarms, and Status Indications

Start Low Coolant Temperature Frequency

Run Customer Selected Faults (2) Power Factor

Oil Pressure Common Alarm Kilowatts

Low Oil Pressure Pre-Alarm AC Volts L1-N Reactive Power - kVAR

Low Oil Pressure Shutdown AC Volts L2-N Energy, mW-hrs.

Coolant Temperature AC Volts L3-N Low Fuel

High Coolant Temp Pre-Alarm Current L1 Low DC Voltage Warning

High Coolant Temp Shutdown Current L2 High DC Voltage Warning

Overcrank Shutdown Current L3 AC Failure to Charger

Overspeed Shutdown

Switch OFF (Not-in Auto)

Logs: User Activity Log, Event Log, and Alarms Acknowledgement Log for automatic record-keeping. All user keyboard commands, events, and alarms/alarm acknowledgements shall be stored in separate logs file for subsequent use and tracking. These logs shall be viewable on the monitor.

Trend Charting and Reports: All available real-time network data shall be individually selectable for trend charting and analysis by the user, with up to six parameters included . Three standard report formats shall be available; one for

Engine Data, one for Generator Data, (See Table.), and one report on the active status of each input/output of the digital I/O modules.

The software shall be upgradeable to include the capability for user-defined report formats.

Auxiliary Equipment Control and Annunciation: Provide as necessary digital I/O modules each with sixteen Form C (5A at 250VAC) relay outputs and four digital inputs to be controlled and read from the network.

Remote Communications: Provide devices and equipment for remote telecommunications from the network to an assigned remote control station personal computer and pager. Include gateway(s), modems and UPS for modems as required. The alarms as individually specified in this section shall be programmed for automatic “dial - out” requested by client to the remote control station.

The manufacturer shall have a service and support network capable of fully supporting the entire system provided. The service and support network shall include a local service organization, with factory trained service and support technicians, and locally available spare parts for all components provided in the system.

H.12.2.34 Generator Earthing (Grounding)

Generator frame shall be connected to the equipment earthing system through a separate equipment earth conductor. In addition a local electrode might be required if generator is appreciably remote from the main electrical room. Neutral and frame of generator shall not be bonded except in the case of local neutral earthing as mentioned above.

H.12.3 Execution

H.12.3.1 Examination

Examine areas, equipment bases, and conditions, with Installer present, for compliance with requirements for installation and other conditions affecting package engine-generator performance.

Examine roughing-in of piping systems and electrical connections. Verify actual locations of connections before packaged engine-generator installation.

Proceed with installation only after unsatisfactory conditions have been corrected.

H.12.3.2 Installation

Comply with packaged engine- generator set manufacturers’ written installation and alignment instructions and with NFPA 110.

Install engine generator to provide access, without removing connections or accessories, for periodic maintenance.

Install engine generator set with restrained spring isolators having a minimum deflection of 25mm on 100mm high concrete base. Secure sets to anchor bolts installed in concrete bases. Concrete base construction is specified in Section “Electrical Supports and Seismic Restraints”.

- EQUIPMENT BASES: ensure that concrete bases and foundations provided for installation of equipment are constructed in accordance with approved shop and construction drawings and manufacturers' equipment drawings and that holes for fixing bolts and provisions for passage of cables etc. are provided as required.
- BUILT-IN ITEMS: ensure that equipment supports, fixings and the like, and sleeves for passage of feeders and cables which are to be built into concrete foundations, bases or building structure are provided as and when required and that they are properly installed.

- **TOOLS:** use only tools recommended by equipment manufacturers for installations, particularly in making connections and adjustments.
- **SUPERVISION:** carry out equipment installation under the direct supervision of a qualified technician, licensed by and trained at the factory. Final adjustments and putting into satisfactory operation are to be made by a specialist delegated by the factory.
- **GENERATING SET:** install to maintain alignment and minimize engine and generator stresses. Protect instrumentation and control equipment including engine mounted instruments from machine vibration. Mountings and method of mounting are to be as recommended by the manufacturer and approved by the Engineer.
- **ENGINE EXHAUST PIPING** is to be slightly sloped away from engine to avoid condensation returning to engine and is to have drain plugs or clean-out at lower end as required.
- **ENGINE HOT-AIR EXHAUST DUCT:** install approved canvas duct with metal frames between radiator and louvered opening in wall for radiator exhaust air.
- **TANK VENT PIPE:** extend to nearest outside wall of building and carry up to at least 2 m above ground level with end at least 1 m away from any building opening. Slope vent pipe back to tank without traps and support securely. Provide replaceable dust filter and gooseneck bend or approved weatherproof vent cap at top of pipe.
- **PIPE HANGERS AND SUPPORTS:** fasten securely to building structure with approved masonry expansion bolts, minimum 20 mm diameter and install in accordance with manufacturers' instructions.
- **EARTHING:** install earthing system in accordance with SUB-SECTION MV Motors of the Specification.

Install Schedule 40, black steel piping with welded joints and connect to engine muffler. Install thimble at wall. Piping shall be same diameter as muffler outlet. Flexible connectors and steel piping materials and installation requirements are as specified in Section “Hydronic Piping”.

- Install condensate drain piping to muffler drain outlet full size of drain connection with a shutoff valve, stainless-steel flexible connector, and schedule 40, black steel pipe with welded joints. Flexible connectors and piping materials and installation requirements are specified in Section “Hydronic Piping”.

Electrical Wiring: Install electrical devices furnished by equipment manufacturers but not specified to be factory mounted.

H.12.3.3 Connection

Piping installation requirements are specified in Sections. Drawings indicate general arrangement of piping and specialties.

Connect fuel, cooling-system, and exhaust-system piping adjacent to engine generator to allow service and maintenance.

Connect engine exhaust pipe to engine with flexible connector.

Connector fuel piping to engines with a gate valve and union and flexible connector.

- Diesel storage tanks, tank accessories, piping, valves, and specialties for fuel systems outside the building are specified in Section “Fuel Oil Distribution”.
- Diesel fuel piping, valves, and specialties inside the building are specified in Section “Fuel Oil Piping”.

Ground equipment according to Section “Grounding and Bonding”.

Connect wiring according to Section “Conductors and Cables”.

H.12.3.4 Identification

Identify system components according to Section “Mechanical Identification” and Section “Electrical Identification”.

H.12.3.5 Field Quality Control

Testing Agency: (Owner will engage) a qualified agency to perform tests and inspection and prepare test reports.

Manufacturer’s Field Service: Engage a factory -authorized service representative to inspect, test and adjust components, assemblies, and equipment installations, including connections. Report results in writing.

Perform tests and inspections and prepare test reports.

- Manufacturer’s Field Service: Engage a factory -authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to asset in testing.

Test and Inspections:

- Perform test recommended by manufacturer and each electrical test and visual and mechanical inspection (expect those indicated to be optional) for “AC Generators and for Emergency Systems” specified in NETA Acceptance Testing Specification. Certify compliance with test parameters.
- NFPA 110 Acceptance Tests: Perform tests required by NFPA 110 that are additional to those specified here including, but not limited to, single-step full-load pickup test.
- Battery Tests: Equalize charging of battery cells according to manufacturer’s written instructions. Record individual cell voltage. a. Measure charging voltage and voltages between available battery terminals for full-charging and float-charging conditions. Check electrolyte level and specific gravity under both conditions. b. Test for contact integrity of all connectors. Perform an integrity load test and a capacity load test for the battery. c. Verify acceptance of charge for each elements of the battery after discharge d. Verify that measurements are within manufacturer’s specifications.
- Battery-Charger Tests: Verify specified rates of charge for both equalizing and float-charging conditions.
- System Integrity Tests: Methodically verify proper installation, connection, and integrity of each element of engine-generator system before and during system operation. Check for air, exhaust, and fluid leaks.
- Exhaust-system Back-Pressure Test: Use a manometer with a scale exceeding 40-inch wg (120kPa). Connect to exhaust line close to engine exhaust manifold. Verify that backpressure at full- rated load is within manufacturer’s written allowable limits for the engine.
- Exhaust Emissions Test: Comply with applicable government test criteria.
- Voltage and Frequency Transient Stability Tests: Use recording oscilloscope to measure voltage and frequency transients for 50 to 100 percent step-load increases and decreases, and verify that performance is as specified.
- Harmonic-Content Tests: Measure harmonic content of output voltage under 25 percent and at 100 percent of rated linear load. Verify that harmonic content is within specified limits.
- Noise level Tests: Measure A-weighted level of noise emanating from generator-set installation, including engine exhaust and cooling-air intake and discharge, at (four) (insert number) locations (on the property line) Insert location for measurement, and compare measured levels with required values.

Coordinate tests with tests for transfer switches and run them concurrently.

Test instruments shall have been calibrated within the last 12 months, traceable to standards of NIST, and adequate for making positive observation of test results. Make calibration records available for examination on request.

Leak Test: After installation, charge system and test for leaks. Repair leaks and retest until no leaks exist.

Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.

Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

Remove and replace malfunctioning units and (retest) (reinspect) as specified above.

Retest: Correct deficiencies identified by tests and observations and retest until specified requirements are met.

Report results of tests and inspection in writing. Record adjustable relay settings and measured insulation resistances, time delays, and other values and observations. Attach a label or tag to each tested component indicating satisfactory completion of tests.

Infrared Scanning: After Substantial Completion, but not more than 60 days after Final Acceptance, perform an infrared scan of each power wiring termination and each bus connection. Remove all access panels so terminations and connections are accessible to portable scanner.

- Follow-up Infrared Scanning: Perform an additional follow-up infrared scan 11months after date of Substantial Completion.
- Instrument: Use an infrared scanning device designed to measure temperature or to detect significant deviations from normal values. Provide calibration record for device.
- Record of Infrared Scanning: Prepare a certified report that identifies terminations and connections checked and that describes scanning results. Include notation of deficiencies detected, remedial action taken, and observations after remedial action.

H.12.3.6 Demonstration

Engage a factory- authorized service representative to train Owner's maintenance personnel to adjust, operate and maintain packaged engine generators. Refer to Section "Demonstration and Training".

H.12.3.7 Visual Inspection

All equipment which form part of the diesel generating plant shall be visually inspected for damage and checked against the manufacturer catalogues/drawings and schedule, for the following:

- Type of generating set
- Serial number
- Engine details
- Alternator, exciter and AVR details
- Rated speed
- Rated voltage
- Number of phases
- Rated frequency
- Rated KVA at continuous rating
- Rated KW at continuous rating
- Rated KVA at service rating
- Rated KW at service rating
- Ancillary equipment

H.12.3.8 Preliminary Inspection Check

Preliminary inspection check shall include the following:

- Alignment of engine/alternator assembly on bed plate.
- Installation of vibration isolators

H.12.3.9 Preliminary Running Test

Preliminary running test to check the following:

- Engine start and stop control
- Engine oil pressure
- Generator voltage and frequency including phase sequence
- Control and protection devices
- Leaks in oil, water and exhaust
- Excessive vibration
- Adjustments of meters and potentiometer related to generated output parameters

H.12.3.10 Load Tests (in Factory)

The set shall be run continuously for 8 hours at rated load followed by 110 percent of rated load for a period of one hour.

Every 15 minutes for the first hour and every hour thereafter, the following parameters shall be recorded:

- All electrical output parameters associated with main alternator.
- Parameters of charging alternator
- Measurements of all engine parameters
- Lubricating oil consumption
- Cooling air medium flow
- Alternator cooling air inlet and outlet temperatures.

Load test shall be secured along with ATS and synchronizing panel at 90%, 100% and 110% loads by arranging external load banks for the performance of the DG set installations.

H.12.3.11 Transient Load Switching

Resistive load shall be applied and switched "ON" and "OFF" in STEPS, with the diesel generator running at rated speed and generating rated voltage.

Transient recordings of maximum, minimum and nominal voltage and frequency levels together with the response times shall be obtained.

H.12.3.12 Insulation Test

Remove all external wiring between the plant and load bank/ test panels.

Isolate sensitive electronic equipment in alternator and control panel as per manufacturers recommendation.

Open any neutral earthing links.

Using 1000V megger check the insulation resistance :

- Between the load terminals and plant structure

- Between the generator terminals and plant structure

Reconnect electronic equipment and neutral earth links.

H.12.3.13 Functional Test

The operation of interlocks and interconnections with all external equipment and controls to be connected on site, shall be simulated as part of these tests.

The generating set shall be tested on Site for manual and automatic operation, for regulation, for sudden load pick-up and for withstanding long lasting load.

H.12.3.14 Routine Tests

Fully assembled plant or equipment is to be tested at the factory and witnessed by two engineers from Consultant Client side, before shipping. Complete performance tests are to be carried out under site simulated conditions, in accordance with the Standards and as described in the Specification.

Inspection and tests on site

EQUIPMENT: inspect equipment upon delivery to Site and report any loss or damage to the Engineer.

EARTHING RESISTANCE TESTS if any are to be carried out to verify specified requirements.

LOAD TESTS are to be carried out at low loads to overload conditions, at various power factors. Measurements are to include voltage and frequency deviations and regulating time under various step loading conditions, temperature measurements and pressure measurements at various locations, and in accordance with an approved plan under conditions equal to worst site ambient conditions.

TESTS are to include:

- Full load test for 8 hours continuous, immediately followed by 10% overload test, without interruption
- Insulation measurement
- Functional tests for voltage sensing, automatic start and synchronization, transfer of load and load-sharing as applicable
- Operation of engine shut-down and alarm signaling and indication, under simulated fault conditions
- Measurement of vibration transmission to building structure

LOAD BANKS: if actual loads are not made available at time of acceptance testing, provide load banks to carry out complete test cycle of the system under loading and switching conditions necessary to prove compliance with the Specification.

PIPING SYSTEM: using carbon dioxide or nitrogen from pressurized cylinder, test each system to 1.5 times normal operating pressure. Do not subject equipment, apparatus or devices to pressure exceeding prescribed test pressure obtained from nameplate data or from manufacturers' published data. Apply tests before connecting piping to equipment. Remove or disconnect and blank off relief valves, instruments and devices that might be damaged by test pressure. Maintain test pressure on system for 24 hours during which time there is to be no noticeable drop in pressure. Check for leaks using soap solution. Isolate source of pressure during testing.

H.13. INSTRUMENTS AND METERING

H.13.1 General

H.13.1.1 General Instructions

Works under this section shall be governed by Conditions of Contract and Section General provisions.

H.13.1.2 Scope

Provide all instruments and metering assemblies/systems as indicated in electrical drawings and specified herein.

H.13.1.3 Codes and Standards

All Electrical indicating instruments shall comply with BS 89 and shall have an accuracy class index as follows:

Function	Accuracy Class Index
Switchboard Indicating Instrument	1.0
Ammeters and Voltmeters on Motor Control Panels	2.5

The current transformers shall comply with all relevant requirements defined in BS 3938.

KVARh meter shall comply with all relevant requirements of BS 5685.

Polyphase meters registering maximum demand in kilowatts or (MW) shall comply with BS 5685:Part 3.

KWH meters shall comply with British Standard BS 5685:Part 1.

The terminal marking shall be in accordance with BS 5472.

Specification for Electrical measuring instruments - BS 89 :1990.

Specification for Voltage Transformers - BS 7625 : 1993.

Specification for Current Transformer - BS 7626 : 1993.

Specification for Watthour Meters - BS EN 60521 : 1995.

Specification for Terminals - BS 5472, EN 50005.

Specification for Electricity meters - BS 5685.

H.13.2 Products

H.13.2.1 Selector Switches

Ammeter selector switch shall have four operating positions marked "R", "Y", "B", "N" and an "OFF" position on a 3 phase, 4 wire supply system. The selector switch shall enable to read the current in each phase and neutral in sequence.

On, 3 wire system, ammeter selector switch shall have these operating positions marked "R", "Y", "B" and an "OFF" position. Ammeter selector switch shall have make-before-break cutouts and shall be connected so that associated current transformers are short circuited where they are not connected to ammeters.

Voltmeters selector switches, operating on 3 phase, 4 wire system. Shall have six operating positions marked "R-Y", "Y-B", "B-R", "R-N", "Y-N", "B-N" and an "OFF" position. Voltmeter switches shall have "break-before-make" cutouts.

All labeling shall be in English and Arabic.

H.13.2.2 Current Transformers

Current transformers shall have an accuracy class designation according to the following table:

No.	Function	Accuracy Class
		Designation
i.	Tariff metering	0.5
ii.	Non Tariff metering	1.0
iii.	Switchboard indicating instruments	1.0
Iv.	Motor starter ammeters	3.0

Current transformers designed for measurement circuits or for protection circuits shall not be used dual purpose role serving both measuring instruments and protection gear.

All CT's shall be of the ring type. Wound primary CT's shall only be accepted where the rated primary current is so low as to make ring type CT's impracticable.

One side of the secondary of each CT shall be connected to earth at one point via a bolted removable link.

For metering circuits a front panel CT test block or a "shorting" terminal within the panel shall be provided for test purposes.

All CT's included for use at voltage exceeding 1000 volts shall be epoxy resin encapsulated.

Dual ratio CT's shall have two separate secondary windings capable of being connected in series or in parallel to give the designed ratio.

Magnetization curves and/or type test certificate shall be provided for all CT's associated with protective devices.

Each CT shall have a rated burden 50 percent greater than the total burden of the instruments, relays, etc. which they serve.

All CT's shall have a rating plate bearing the information as stipulated in BS 3938.

H.13.2.3 Voltage Transformers

Voltage transformers shall be of the type, rating and voltage ratios as specified in the Schedules or as indicated on the Contractor's approved shop drawings.

All voltage transformers shall have an accuracy class designation according to the following table:

No.	Function	Accuracy Class
		Designation
i.	Metering	1.0
ii.	Switchboard indicating instruments	1.0
iii.	Motor starter ammeters	3.0

Voltage transformers shall comply with all relevant requirements of BS 3941 and shall be suitable for use in the specified service condition.

Voltage transformers designed for primary voltage less than 4000 volts shall be air insulated type with winding encapsulated in epoxy resin or other suitable synthetic material.

Each voltage transformer shall have a rated burden at least 50 percent higher than the total burden of the apparatus or instruments it serves.

The insulation resistances of each voltage transformer shall be indelibly marked on the shipping/dispatch label.

H.13.2.4 Meters

All single phase and 3-phase integrating meters like watt-hour meter, Kwh meter, maximum demand meter.

Polyphase maximum demand meters shall operate on the basis of 30 minutes demand integration period.

Provision for transmission of data to external devices shall be made for the following:

- Kilowatt - hour consumption.
- Kilowatt - maximum demand
- Time reset pulse for maximum demand.

All meters covered in the preceding clauses shall have an accuracy class designation of 2.5 or better.

All Three phase meters shall be suitable for operation on a 4-wire system with unbalanced load.

Phase Rotation & Accuracies Phase sequence reversal shall have negligible effect on the accuracy of the kWh meters described; Meters shall be approved by the Local Electrical Authorities and other relevant parts of this standard as indicated below:

kWh meters Part 4 (IEC 43)

Maximum demand meters Part 5 (IEC 211)

House Service Case The case shall be formed from high impact black phenolic resin mouldings; base and terminal block mouldings from a single unit. The cover shall be secured to the base by three captive screws while a cord gasket of large section shall ensure a dust-tight joint. The standard terminal cover shall fit flush with the terminal block, alternatively an extended cover shall be available which shall shroud the service cables. Both cover and terminal cover screws shall have facility for sealing.

Meter terminal shall be loose inserts fitted from inside the meter into cavities in the terminal block; moulded barriers between terminals shall provide adequate anti-creep surfaces. Terminal shall be made of brass and shall be heavily plated to inhibit corrosion. Terminal holes shall be minimum 8mm diameter up to 50 amperes rating and 12.7 mm diameter for the 100 ampere rating. The 100 ampere rating shall be specially designed to cope with high current flow through combination of the use of copper, machine finished terminations and heavy duty plated brass inserts in the terminal block. Terminal blocks shall have connection facilities for a wide range of tariff metering. A diagram of connections shall be fixed inside the terminal cover.

Switchboard Case The switchboard drawout pattern case shall be supplied for either flush or projection mounted as acceptable to Engineer. The meter main frame element shall be secured to a cradle that can be withdrawn from the case to allow the meter to be inspected or serviced. A high pressure shall be maintained between the case and cradle contacts to ensure negligible contact resistance.

Terminals connected to current transformer secondaries shall have shorting switches which automatically close as the cradle is withdrawn from its case.

A diagram of internal connections shall be fixed inside the meter case.

Frame and Elements A rigid die casting of high quality silicon aluminium alloy shall form the main frame to which the meter elements shall be secured. Each element shall have a torque balance, a low load and an inductive load calibration adjuster: These shall be all linear in effect and shall be readily accessible. Protection against corrosion shall be given by electropainting the frame and elements to produce a durable synthetic resin coating.

Meter Coils The voltage and current coils shall be encapsulated in polypropylene (except for 100A current coils where epoxy resin shall be used). Encapsulation shall protect the meter against high voltage surges resulting from electrical storms and system transients, in addition to rendering the coils waterproof. Voltage coils shall be machine wound in a polyurethane coated wire. Current coils shall be wound from large section copper strip designed to provide a wide load range by withstanding continuous overloads. **Bearings** The weight of the rotor shall be supported by a symmetrical magnetic field set up by fixed and moving high coercivity permanent magnets, leaving only small transverse forces to be contained by fixed pin and guide bearings at each end of the rotor shaft.

Guide pins shall be of polished stainless steel running in guides precision moulded from specially selected low friction material.

Temperature compensation for the magnets shall be provided over a temperature range of - 20 degree C to + 60 degree C.

Rotor System The rotor disc shall be light and rigid and shall be die cast or moulded to an aluminium alloy shaft. For stroboscopic calibration 500 serrations shall cut in the edge of the disc and for testing purposes the upper surface shall have 100 and 240 division concentric circles marked in black round the periphery. Two anti-creep holes in the disc shall prevent rotation on voltage alone. A non-reverse device shall be fitted to the rotor shaft to prevent the meter from registering under reverse power flow conditions. A highly polished worm cut in the rotor shaft shall form the register drive.

Brake Magnet A bi-polar brake magnet unit mounted in a die cast aluminium alloy housing shall be provided. Two approved bar magnets shall be employed, producing a uniform field which shall be symmetrical about the centre line of the disc gap, thus minimizing the effect of disc height variations.

Registers Three types of interchangeable register shall be possible to be fitted to polyphase meters, the final selection being left to the Engineer:

Large jumping figure cyclometer.

Continuously driven cyclometer.

Pointer pattern.

All forms of register shall have precision moulded lightweight gears which shall give strength with extremely low frictional effects. Gear wheels and pinions shall be moulded on to hard drawn and polished stainless steel shafts.

Mouldings shall extend along the shafts to provide end shake shoulders and low friction surfaces against the metal support plates. Register dials shall be clearly marked in the appropriate units.

H.13.2.5 Terminals

Cable terminals shall be suitable for the specified cable sizes. Adequate space shall be provided for cable terminations.

Terminal blocks shall be made of thermosetting melamine or polyamide material with good flame resistance. Terminal blocks shall withstand a temperature rise of 90o C above the ambient temperature. Cable terminals shall have permanent label fitted to each terminal, for indication of its purpose.

Termination of standard cables shall be done by using copper or copper alloy ferrules of sizes suitable for accommodating all strands of the cable.

All auxiliary wiring except screened cables shall be connected to incoming/outgoing cables via insulated terminal blocks, screw/screw type, clipped on DIN rails. Sufficient spare space shall be allowed on the DIN rails for addition of terminal blocks in the future.

Termination of screened cables shall be done by using plugs and fixed sockets.

All terminal blocks shall be mounted at minimum 20 cms above the base of floor mounted assemblies.

H.13.2.6 General Requirements for Meters

All electrical indicating instruments shall be products of a single manufacturer.

All ammeters and voltmeters shall be the moving iron type.

All instruments shall be flush mounted.

The scale range of ammeters, voltmeters, wattmeters and VAR meters shall be such that under normal operating conditions, the instruments pointer shall read between 60-75% of their effective scales. The scale span of these meters shall not be less than 90 degrees.

Ammeters for use in motor control centres shall have a maximum burden of 3 VA at the upper limit of the effective range.

Starters shall have extended scales with maximum scale indication equal to minimum six times the upper limit of the effective scale range. The scale shape shall be such that the effective scale range is not less than two thirds of the total scale span.

The use of resistive ammeter shunts for extending the range of ammeters will not be acceptable.

Power factor meters shall be marked LEAD and LAG in the appropriate quadrants.

Indicating wattmeters shall be of air cored dynamometer type 3 phase indicating meters suitable for operation on a 3 phase, 4 wire system with balanced load, unless otherwise specified.

VAR meters shall be supplied complete with the appropriate phase shifting transformer.

All instruments shall be equipped with external means for adjusting the zero indication.

H.13.3 Execution

(NOT USED)

H.14. UNDERGROUND DISTRIBUTION

H.14.1 General

H.14.1.1 Description

General:

- Furnish all labour, materials, tools, equipment, and services for underground distribution, in accord with provisions of Contract Documents.
- Completely coordinate with the work of other trades.
- Although such work is not specifically indicated, furnish and install all supplementary or miscellaneous items, appurtenances and devices incidental to or necessary for a sound, secure and complete installation.

Related sections:

- General Provisions for Electrical Works.

- General requirements.

All excavation is unclassified.

Definitions: Unclassified excavation: Excavate and grade all materials that can be removed without drilling or blasting.

H.14.1.2 Quality Assurance

Compaction density test: ASTM D1557.

Conduct in place moisture density tests to insure that all work complies with this specification.

Comply with all aspects of "Safety Rules & Regulations for Excavation" as appropriate to Standard Codes and Practice.

H.14.1.3 Submittals

Shop drawings: Required for Owner's review. B. Product data: Required for Owner's review.

Contract closeout information: Operating and maintenance data.

H.14.1.4 Job Conditions

Protect existing utilities and structures as indicated in Section General provisions for Electrical work.

Avoid overloading Keep surcharge sufficient distance back from edge of excavation to prevent slides or caving Maintain and trim excavated materials in such a manner to be as little inconvenience as possible to public and adjoining property owners.

Provide full access to public and private premises, to fire hydrants, at street crossings, sidewalks and other points as designated by Owner to prevent serious interruption of travel.

H.14.1.5 Product Delivery, Storage and Handling

Store conduit to avoid warping or deterioration.

Store plastic conduit on flat surface protected from direct rays of sun.

H.14.2 Products

H.14.2.1 Duct System

Primary duct system: Multiple single, round bore PVC conduits completely encased in concrete as shown on plans.

- Rigid PVC conduit: As specified in Section Medium voltage Cables and accessories.
- Separators: Concrete, plastic or other non metallic, non decaying material.
- Concrete: 20685 KPa Conform to requirements.

Pull wire: No.9 galvanized iron, or heavy nylon cord, free of kinks and splices.

H.14.2.2 Manholes

Electric and telephone manholes: Types as indicated.

- Concrete: 27580 KPa Conform to requirements.
- Cover and frame: 914.4 mm diameter, gray cast iron, with machine finished seat for perfect joint between cover and frame.
- Provide floor drain with grate.
- Provide cable racks, ladder rungs, 2 ground rods, cable pulling eye.

Cable racks: Galvanized, mounted on wall.

- Equip with minimum of 8 adjustable hooks; minimum 2 spare hooks on each rack.
- Insulators: Best quality, high glazed porcelain; provide for each hook.
- Space racks so each end of splices are supported horizontally.

Ladder rungs: Galvanized, 300 mm x 300 mm x 20 mm diameter.

- Set with 200 mm clearance from rung to wall.

Ground rods: 20 mm x 3 meter long, copper weld.

H.14.2.3 Backfill Material

Backfill material: As approved by the Owner.

- Free of rock cobbles, roots, sod or other organic matter, and frozen material.
- Moisture content at time of placement: 3 percent plus/minus of optimum moisture content, as tested in accord with ASTM D1557.

H.14.3 Execution

H.14.3.1 Excavating and Trenching General

Remove and dispose of materials determined by the Owner to be unsuitable. Trench, backfill and compact for all underground utilities.

H.14.3.2 Trench Excavation

Excavate trenches by open cut method to depth indicated and necessary to accommodate the work.

- Permission may be granted for tunnel work for crossing under crosswalks, driveways or existing utility lines.
- Such tunnels are limited to 3 meter in length.

Open no more than 300 linear metres of trench at one time, or less, as required by the Owner. Failure to comply may necessitate shutdown of entire project until backfilling is performed.

Carry rock excavations minimum of 300 mm below indicated grades.

Avoid over excavating below indicated grades unless required to remove unsuitable material.

Back fill over excavations in firmly compacted 150 mm lifts.

Trench size: Excavate only sufficient width to accommodate free working space.

- Cut trench walls vertically from bottom of trench to top of conduit.
- Trench width at top of conduit may not exceed outside diameter of utility service by more than following dimensions:

Overall Diameter of Utility Service Excess Dimension 850 mm and less 400 mm More than 850 mm 600 mm

Keep trenches free of water.

Brace and sheet trenches as soil conditions dictate. Do not remove until backfilling has progressed to a stage that no damage to conduit will result due to removal.

H.14.3.3 Removal of Existing Utilities

Remove existing utilities where indicated.

Under new construction, plug and/or cap and protect existing utilities. Pay fees for existing services capped at mains in street.

H.14.3.4 Installation of Primary Duct System

Lay all duct lines to minimum grade of 100 mm in 34 metre. Grade may be from one manhole to next, or both ways from high point between manholes, depending on contour of finished grade.

Install duct lines so that top of concrete is not less than 750 mm below finished grade or finished paving at any point.

Accomplish changes in direction of runs exceeding total of 10 degrees, either vertical or horizontal, by long sweep bends with minimum radius of 8 metres.

- Manufactured bends may be used at ends of short runs of 34 or less.
- Long sweep bends may be made up of one or more curved or straight sections and/or combinations thereof.
- Manufactured bends: Minimum radius of 900 mm for ducts of 75 mm in diameter and larger.

Place conduit joints in concrete encasement side by side horizontally.

Terminate conduits in end bells where duct lines enter pull boxes or manholes.

Thoroughly clean conduit before using or laying.

Lay no conduit in water or in unsuitable weather or trench conditions.

During construction and after duct line is completed, plug ends of conduits to prevent water washing into conduit or manholes. Take particular care to keep conduits clear of concrete, dirt, and any other substance during course of construction.

Where it is necessary to cut tapered end on a piece of conduit at site, make cut with tool or lathe designed to cut taper to match taper of particular conduit being used.

After duct line has been completed, pull standard flexible mandrel not less than 300 mm long, with diameter approximately 6.3 mm less than inside diameter of conduit, through each conduit.

Then pull brush with stiff bristles through each conduit to make certain that no particles of earth, sand, or gravel have been left in line.

Pneumatic rodding may be used.

Install pull wire in all unused new ducts. Extend minimum of 1 metre into each manhole or above pads beyond ends of ducts.

Encase each conduit completely in concrete not less than 75 mm beyond any surface of conduit.

- Do not place concrete until conduits have been inspected by the Owner.
- Mix, place and cure concrete in accord with specific requirements.

Provide uniform spacing between conduits: Not less than 12.50 mm

- Place separators on maximum 1.2 metre centers.
- Securely anchor ducts to prevent movement during placement of concrete.

Make conduit joints in accord with manufacturer's recommendations for conduit and coupling selected.

- Make conduit joints watertight.
- Make plastic conduit joints by brushing plastic solvent cement on inside of plastic coupling fitting and outside of conduit ends.
- Slip conduit and fitting together with quick one quarter turn twist to set joint tightly.

H.14.3.5 Installation of Manholes

Determine exact location of each manhole after careful consideration has been given to location of other utilities, grading, and paving. Do not begin construction until location of each manhole has been approved by the Owner.

Construct manholes of type indicated in accord with applicable details. Mix, place and cure concrete in accord with specific requirements.

Set frames and covers.

- Paint with 2 coats asphaltic paint after inspection and approval by the Owner, and before setting.
- In paved areas, set top of manhole covers flush with finished surface of paving.
- In unpaved areas, set top of manhole covers approximately 12.5 mm above finished grade.
- Where existing grades are higher than finished grades, install sufficient number of courses of curved segmented concrete block between top of manhole and manhole frame to temporarily elevate manhole cover to existing grade level.

Install cable racks, ladder rungs and cable pulling iron.

Drive 2 ground rods into earth not less than 3 metre before manhole floor is placed. Extend ground rods approximately 100 mm above manhole floor.

H.14.3.6 Backfilling

Do not backfill until all tests are performed on system, and system complies with specified requirements.

Hand or pneumatic tamp backfill around and over pipe in lifts not exceeding 200 mm loose thickness.

Compact to density specified, so pipe will not be injured.

Exercise care in backfilling operations to avoid displacing pipe joints either horizontally or vertically and to avoid breaking pipe.

Do not water flush for consolidation.

H.14.3.7 Compaction

Compact all trench backfill in areas under paved roads, parking areas, sidewalks and other structures as directed by the Owner to at least 95 percent of maximum dry density.

In locations where trench will not be under paved areas, compact backfill to minimum 90 percent of maximum dry density.

H.14.3.8 Field Quality Control

Perform backfill density tests as directed by the Owner. Allow for one test per 30 metre of trench.

H.15. ENCLOSED SWITCHES AND CIRCUIT BREAKERS

H.15.1 General

H.15.1.1 Related Documents

Drawings and general provision of the Contract, including General and Supplementary Conditions and other Specification Sections, apply to this Section.

H.15.1.2 Summary

- No fusible switches.
- Enclosures.

H.15.1.3 Definitions

- GD: General duty.
- GFCI: Ground-fault circuit interrupter.
- HD: Heavy duty.
- RMS: Root mean square.
- SPDT: Single pole, double throw

H.15.1.4 Submittals

Product Data: for each type of enclosed switch, circuit breaker, accessory, and component indicated. Include dimensioned elevations, sections, weights, and manufacturer's technical data on features, performance, electrical characteristics, ratings, and finishes.

- Enclosure types and details for types other than NEMA 250, Type 1.
- Current and voltage ratings.
- Short-circuit current ratings.
- UL listing for series rating of installed devices.
- Features, characteristics, ratings, and factory settings of individual over current protective devices and auxiliary components.

Shop Drawings: Diagram power, signal and control wiring.

Field quality-control test reports including the following:

- Test procedures used.
- Test results that comply with requirements.
- Results of failed test and corrective action taken to achieve test results that comply with requirements.

Manufacturer's filed service report.

Operation and Maintenance Data: for enclosed switches and circuit breakers to include emergency, operation and maintenance manuals. In addition to items specified in Section (Operation and Maintenance Data) include the following:

H.15.1.5 Quality Assurance

Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing acceptable to authorities having jurisdiction, and marked for intended use.

Comply with NFPA 70.

Product Selection for Restricted Space: Drawings indicate maximum dimensions for enclosed switches and circuit breakers, including clearances between enclosures, and adjacent surfaces and other items. Comply with indicated maximum dimensions.

H.15.1.6 Project Conditions

Environmental Limitations: Rate equipment for continuous operation under the following conditions, unless otherwise indicated:

- Ambient Temperature: minus 5 deg 0 and not exceeding (45degC).

H.15.1.7 Coordination

Coordinate layout and installation of switches, circuit breakers, and components with other construction, including conduit, piping, equipment, and adjacent surfaces. Maintain required workspace clearances and required clearances for equipment access doors and panels.

H.15.2 Products

H.15.2.1 Manufacturers

In other Part 2 articles where titles below introduce lists, the following requirements apply to product selection:

Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, manufacturers specified.

Manufacturers: Subject to compliance with requirements, provide products by one of the manufacturers specified.

H.15.2.2 Fusible and Nonfusible Switches

Accessories:

- Equipment Ground Kit: Internally mounted and labeled for copper and aluminum ground conductors.
- Neutral Kit: Internally mounted, insulated capable of being grounded and bonded and labeled for copper and aluminum neutral conductors.
- Auxiliary contact Kit: Auxiliary set of contacts arranged to open before switch blades open.

H.15.2.3 Enclosures

Enclosures shall be metallic and shall be treated with a rust – inhibiting phosphate, and finished in Gray backed enamel.

H.15.3 Execution

H.15.3.1 Examination

Examine elements and surfaces to receive enclosed switches and circuit breakers for compliance with installation tolerances and other conditions affecting performance.

Proceed with installation only after unsatisfactory conditions have been corrected.

H.15.3.2 Concrete Bases

Coordinate size and location of concrete bases. Verify structural requirements with structural engineer.

H.15.3.3 Installation

Mount individual wall-mounting switches and circuit breakers with tops at uniform height, unless otherwise indicated. Anchor floor-mounting switches to concrete base.

Comply with mounting and anchoring requirements specified in Section “Hangers and Supports for Electrical Systems”.

Temporary Lifting provisions: Remove temporary lifting eyes, channels, and brackets and temporary blocking of moving parts from enclosures and components.

H.15.3.4 Identification

Identify field-installed conductors, interconnecting wiring, and components; provide warning signs as specified in Section “Electrical Identification”.

Enclosure Nameplates: Label each enclosure with engraved metal or laminated-plastic nameplates as specified in Section “Electrical Identification”.

H.15.3.5 Field Quality Control

Manufacturer’s Field Service: Engage a factory -authorized service representative to inspect, test and adjust field-assembled components and equipment installation, including connection and to assist in field testing report results in writing.

Prepare for acceptance testing as follows:

- Inspect mechanical and electrical connections.
- Verify switch and relay type and labeling verification.
- Verify rating of installed fuses.
- Inspect proper installation of type, size, quantity and arrangement of mounting or anchorage devices complying with manufacturer’s certification.

Testing Agency: Owner will engage a qualified testing and inspecting agency to perform field tests and inspection and prepare test reports.

H.16. DISCONNECT SWITCHES

H.16.1 General

H.16.1.1 Description

General:

- Furnish all labour, materials, tools, equipment, and services for disconnect switches, in accord with provisions of Contract Documents.
- Completely coordinate with the work of other trades.
- Although such work is not specifically indicated, furnish and install all supplementary or miscellaneous items, appurtenances and devices incidental to or necessary for a sound, secure and complete installation.

Related work specified elsewhere:

- General Provisions for Electrical Work.

Disconnect switches: Quick-make quick-break, heavy duty type in NEMA 1 enclosure.

- In damp areas use NEMA 3R enclosures.
- Switches for motor circuits horsepower rated.
- Fusible where required.

H.16.1.2 Submittal

Shop drawings: Required for Owner's review.

Product data: Required for Owner's review.

Contract closeout information:

- Operating and maintenance data.
- Maintenance materials: Spare fuses, 10 percent or minimum of 3 of each type and rating of installed fuses .

H.16.1.3 Related Equipment Specified Elsewhere

Fusible switches for use in distribution equipment which has to be isolated in the event of short circuit.

H.16.2 Products

H.16.2.1 General

All goods and products covered by these specifications shall be approved by Owner and conforming with the requirements of specifications. Procurement of all goods and products must be approved by the Owner.

H.16.2.2 Safety Switches

Safety switches: Fusible and non-fusible type, NEMA Type HD Heavy Duty construction, unless otherwise indicated

- Enclosure: NEMA 1 unless otherwise indicated.
- Switch blades fully visible in OFF position with door open.
- Contact operation quick-make and quick-break.
- Provide padlocking provisions in OFF position.
- Finish: Baked enamel over rust-inhibiting primer.
- Provide weatherproof disconnect switches as required by Section General provisions.
- Shall be equipped with line terminal shields.

H.16.2.3 Fuses

All fuses shall be of high rupturing capacity type, fast-acting or time delay types according to requirement.

H.16.3 Execution

H.16.3.1 Installation

Install as indicated and in accord with manufacturers instructions and recommendations. Fabricate and install steel frame where necessary to mount the switches. Locate switches adjacent to the motor or equipment required isolation for maintenance purpose.

H.17. SWITCH BOARDS (MAIN DISTRIBUTION BOARDS)

H.17.1 General

H.17.1.1 Related Documents

Drawings and general provisions of the Contract, including General and Supplementary Conditions and General Specification, apply to this Section.

H.17.1.2 Summary

This Section includes service and distribution switchboards rated 600V and less.

The switchboards are identified as MDB and include all the boards that are directly fed from transformers.

The switchboards shall always be supplied, installed and connected with the all the elements, items, systems listed in the specifications and shown on the Contractor's approved shop drawings including all the BMS interface.

H.17.1.3 Submittals

Product Data: For each type of switchboard, over current protective device, ground-fault protector, accessory, and component indicated. Include dimensions and manufacturer's technical data on features, performance, electrical characteristics, ratings, and finishes.

Shop Drawings: For each switchboard and related equipment.

1. Dimensioned plans, elevations, sections, and details, including required clearances and service space around equipment. Show tabulations of installed devices, equipment features, and ratings. Include the following:
 - Enclosure types and details.
 - Current and voltage transformer ratios, class, terminal markings and output.
 - Instruments, including scale details.
 - Relay types and characteristics.
 - Indicating lamps, including colour.
 - Position of switches and details of function.
 - All internal connections with terminal markings.
 - Arrangement of terminal blocks.
 - Wire numbers.
 - Size, type and colour of secondary wiring.
 - Principal physical dimensions, including clearances required for removing covers, opening doors, operating handles, withdrawing equipment, etc.
 - Position of all panel face equipment.
 - Identification of all equipment, and appropriate label inscriptions.
 - Foundation details, including weights and fixing points.
 - Cable entry details including gland and gland plate provisions.
 - Bus configuration, current, and voltage ratings.
 - Short-circuit current rating of switchboards and over current protective devices.
 - Descriptive documentation of optional barriers specified for electrical insulation and isolation.

- Utility company's metering provisions with indication of approval by utility company.
- Mimic-bus diagram.
- UL or IEC listing for series rating of installed devices.
- Features, characteristics, ratings, and factory settings of individual over current protective devices and auxiliary components.
- Full coordination and selectivity study between breakers in MDSB, MEDSB, DP, PP, MCC, MSP and PCP. Study shall be based on approved software findings.

2. Wiring Diagrams: Power, signal and control wiring.

Samples: Representative portion of mimic bus with specified finish, for color selection.

Field quality – control test reports including the following:

- Test procedures used.
- Test results that comply with requirements.
- Results of failed tests and corrective action taken to achieve test results that comply with requirements.

Operation and Maintenance Data: for switchboards and components to include in emergency, operation, and maintenance manuals include the following:

- Routine maintenance requirements for switchboards and all installed components.
- Manufacturer's written instructions for testing and adjusting over current protective devices.
- Time-current curves, including selectable ranges for each type of over current protective device.
- Full detailed calculation sheets for heat dissipation.

H.17.1.4 Quality Assurance

Testing Agency Qualifications: An independent agency, with the experience and capability to conduct the testing indicated, that is a nationally recognized testing laboratory.

Source Limitations: Obtain switchboards through one source from a single manufacturer. Local manufacturer who do not have official international license issued by international approved panel manufacturer who are fully certified as manufacturers of Type tested switchboards, shall be disqualified.

Product Selection for Restricted Space: Drawings indicate maximum dimensions for switchboards including clearances between switchboards and adjacent surfaces and other items. Comply with indicated maximum dimensions.

Electrical Components, Devices and Accessories: Listed and labeled as defined in NFPA 70, Article 100, or corresponding IEC standards by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

H.17.1.5 Delivery, Storage, and Handling

Deliver in sections or lengths that can be moved past obstructions in delivery path.

Store indoors in clean dry space with uniform temperature to prevent condensation. Protect from exposure to dirt, fumes, water, corrosive substances, and physical damage.

If stored in areas subjected to weather, cover switchboards to provide protection from weather, dirt, dust, corrosive substances, and physical damage. Remove loose packing and flammable materials from inside switchboards; install electric heating (250 W per section) to prevent condensation.

H.17.1.6 Project Conditions

Environmental Limitations: Rate equipment for continuous operation under the following conditions, unless otherwise indicated.

Calculation sheets shall be provided indicating the final temperature reached within enclosure taking into account all heat dissipation sources and ambient temperature.

- Ambient Temperature: Not exceeding (50 deg C).

All necessary ventilation to be integrated within enclosure to avoid any derating of breakers and busses, otherwise larger rating of breakers shall be used at not extra cost.

Coordinate layout and installation of switchgear and components with other construction including I conduit, piping, equipment, and adjacent surfaces. Maintain required clearances for workspace and equipment access doors and panels.

Coordinate size and location of concrete bases. Concrete, reinforcement, and formwork requirements.

H.17.1.7 Extra Materials

Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

Supply as maintenance stock, additional circuit breakers, amounting to one unit for every 10 units, but not less than 2 units of each type and rating.

- Potential Transformer Fuses: Equal to 10 percent of amount installed for each size and type, but no fewer than 2 of each size and type.
- Control-Power Fuses: Equal to 10 percent of amount installed for each size and type, but no fewer than 2 of each size and type.
- Fuses and Fusible Devices for Fused Circuit Breakers: Equal to 10 percent of amount installed for each size and type, but no fewer than 3 of each size and type.
- Fuses for Fused Switches: Equal to 10 percent of amount installed for each size and type, but no fewer than 3 of each size and type.
- Fuses for Fused Power-Circuit Devices: Equal to 10 percent of amount installed for each size and type, but no fewer than 3 of each size and type.
- Indicating Lights: Equal to 10 percent of amount installed for each size and type, but no less than 1 of each size and type.

H.17.2 Products

H.17.2.1 General

This specification relates to Type Tested Assemblies (TTA) and Partially Type Tested Assemblies (PTTA), in accordance with IEC 60 439-1 Standard.

Switchboards that are not type tested shall be rejected.

The switchboard shall be suitable for operating on 3 phase, 4 wire, 380 volts, and ...50/ 60 Hz supply.

The symmetrical fault rating shall be 50 KA for 1 second. The switchboard shall be ASTA tested at the fault; copies of the test certificates shall be submitted for Engineer's approval.

LV power distribution boards/switchboards shall be designed and constructed to withstand for one second without damage, thermal and mechanical stresses which might arise under short circuit conditions up to the prospective busbar short circuit current. LV power distribution boards shall be type tested in compliance with BSEN 60439

The switchboard shall be compartmentalized with individual columns for all frames sizes larger than 800A and manufactured to IEC 439-1, Form (3a) rated- or as shown on the Contractor's approved shop drawings and B.O.Q-, as described hereafter. All the internal separation must be metallic type electro zinc plated.

The equipment shall be suitably constructed for safe, proper and reliable operation without undue wear, corrosion, heating or other operating trouble.

All breakers and controls shall be manufactured exclusively by manufacturer with minimum 15 years of experience in the manufacturing of similar breakers.

The design and arrangement of the equipment shall be subject to the approval of the Engineer.

The Engineer shall have the full discretion any authority to reject part or total assembly work of local representative of approved switchboard manufacturer makes and to insist for switchboard to be manufactured in country of origin.

Unless otherwise noted the main breakers and breakers above 800A frame shall be Air circuit breaker withdraw able, motorized, Hand charged spring, 3 or 4 poles as indicated on drawings with the following features:

Ics = 50kA for 1 seconds

Safety shutter

4 auxiliary contacts - ON/OFF signaling status

2 Alarm auxiliary contacts

Trip unit LT, ST, INST.

It shall monitor voltage, current, frequency, power factor, kVA, kW.... And be equipped to communicate with external hardware and software for the purpose of monitoring and measurement.

All the branch circuit breakers with frame size 800 A and less shall be Molded Case type, fixed/ motor operated and with number of poles as indicated on the Contractor's approved shop drawings, with the following features:

ICS = 50kA.

2 auxiliary contacts - ON/OFF signaling status

1 Alarm auxiliary contacts

Trip unit LT, ST, INST

The Main incoming as well as the outgoings shall be equipped with a power digital meter including a Modbus communications as per the Contractor's approved shop drawings and BMS schedule.

The arrangement of the equipment within the assemblies shall be individually mounting type in a modular arrangement and shall be such as to afford maximum accessibility to all parts, incoming and outgoing wires and cables.

The main distribution switchboard shall be factory built assembly, metal clad, totally enclosed box type, type tested at the factory, complying with B.S. 5486/IEC 439-1 Form (3a).

All plastic parts shall be self-existing withstanding at 460 deg. C as per IEC 695-21 and NFC 20, 455 classes VD (UL 94).

Surge arrestors protection shall be provided at incoming feeder entry point and shall be coordinated with Surge arrestors protection located down stream at entry point of feeder of panel fed directly from main switchboard.

Approved nameplates, permanently mounted for identification of all major and control equipment shall be provided as described under "GENERAL".

Main steel work should be electro zinc plated and passivated followed by stove powder, finish colour shall be RAL 7032.

The switchboard shall comply with the latest versions of: IEC / EN 60 439-1, VDE 0660 part 500, DIN EN60 439-1

Part 1, Salt mist test of IEC 68.2.30.

Switchboards shall be provided with ventilation system in order to derate the tripping setting of breakers and the ampacity of busbars.

Switchboard supplier shall provide all necessary calculation sheets in order to verify that maximum heat dissipated inside end-enclosure does not exceed the maximum allowable temperature T of the circuit breaker without derating the circuit breaker.

If during or after execution stage the temperature inside the end-enclosure exceeds that value T , the breaker will be replaced at no cost by a larger breaker.

Structural steel base shall be provided for securing entire assembly to floor.

In general, manufacturer's standardized construction is desired.

Switchboards shall be provided with adequate lifting means and shall be capable of being rolled or moved into installation and bolted directly to the floor without the use of floor sills.

The Contractor must at an early stage provide the Engineer with all the necessary manufacturer's details and shop drawings concerning the assembly to allow him to check the design of the concrete structure, particularly concerning the loads, the overall dimensions and the cable grouting holes.

Terminal identification and marking shall be in accordance with IEC 9471 and IEC 60445.

Supplies for control circuits shall be taken from within the compartment of the related item of switchgear, and a fuse unit fitted with a separate protective device shall be fixed within the compartment to protect the control circuit. Where control circuits pass through auxiliary contacts the protective device shall also be the means of isolation for the terminals of these contacts.

Where auxiliary contacts are used for interlocking purposes and supplies are derived from other sources, isolating facilities shall be provided to ensure that the auxiliary contacts can be made safe. The isolating facility shall be in the form of an auxiliary contacts switch on the respective compartment isolating device or a separate isolator mounted within the respective compartment. Where a separate isolator is provided a clear warning notice made from "Formica" engraving laminate shall be fixed by screws in a prominent position in the compartment stating "WARNING - ISOLATOR AUXILIARY CONTACTS".

Where the cables to or from the switchboards are shown on the Contractor's approved shop drawings as being PVC or XLPE insulated twin and multi-core cables, armoured or un-armoured, the appropriate units of the switchboard shall be supplied with suitable brass compression glands of the correct sizes.

Compression glands for PVC insulated and sheathed twin and multi-core cables shall comply with the requirements given elsewhere in the specifications. All component parts of a cable gland shall be of the same manufacture.

Provide complete copies of certificates (including drawings) for rating and short circuit withstand strength for the incoming bus-bars, outgoing bus-bars and main horizontal bus-bars. Certificates should be 50kA/1sec, rated at ambient temperature and maximum temperature rise of 50 degC. The certificates must include the actual configuration of the bus-bars proposed for the project.

These specifications require that only fully type-tested assemblies will be accepted and that fully fault tested bus-bars assembled are required. Accordingly the following test reports must be presented:

Verification of temperature – rise limits, clause 8.2.1 of IEC60439-1

Verifications of the dielectric properties, clause 8.2.2 of IEC 60439-1

Verifications of the short-circuit with stand strength, clause 8.2.3 of IEC 60439-1

Verifications of the effectiveness of the protective circuit, clause 8.2.4 of IEC 60439-1

Verifications of clearance and creepage distances, clause 8.2.5 of IEC 60439-1

Verifications of mechanical operation, clause 8.2.6 of IEC 60439-1

Verifications of the degree of protection, clause 8.2.7 of IEC 60439-1

Verifications of the resistance of insulation materials to abnormal heat fire (glow-wire test), clause 8.2.9 of IEC 60439-1

Provide arc test report according to the Swedish handbook SEK 405, Australian standard 1136 and IEC298

Provide full drawings showing the bus-bars how the vertical and horizontal bus-bars are compartmented. They should be fully segregated as per the required Form to IEC 60439-1

Provide full drawings showing the inner segregation plates as well as functional units.

Provide confirmation that the enclosure will be made from electro-galvanized sheet steel or Aluzinc sheet steel.

EMC emission shall be in compliance with EN/IEC Standards EN 50081, EN 50082.

H.17.2.2 Manufacturer

Subject to compliance with the following requirements, switchboard shall be the product, manufacturer and assembly of a manufacturer who is certified ISO 9000, 9001 or 9002 the manufacturer certificates must be presented.

The manufacturer of this equipment shall have produced similar electrical equipment for a minimum period of seven (7) years. Manufacturers shall be approved only if they can meet the presented specifications, and if they are guaranteed by an international company. When requested by the Engineer, an acceptable list of installations with similar equipment shall be provided demonstrating compliance with this equipment.

The manufacturer shall thoroughly test the assembled switchboard for proper functioning with the following specifications. Submit certification to the Engineer that this testing has been completed and that the function and compliance conform to the specification.

H.17.2.3 Construction of the Assembly

The assembly shall consist of a completely enclosed self supporting metal structure, containing circuit protective devices and all other associated equipments as indicated on the Contractor's approved shop drawings and/or specified under other Clauses.

The assembly shall consist of the required number of formed and welded electrozincated or Aluzinc sheet steel enclosures required to mount circuit protective devices and other equipments.

The metal sheets that are in close proximity of high currents shall be made of aluminum.

Bolted frames shall be provided at the rear to support and house copper bus bars, cables and other accessories.

Front, side and top plates shall be steel, removable and not less than 2 mm thickness.

Hinged Front Panels: Allow access to circuit breaker, metering, accessory, and blank compartments

All fastenings between structural members shall be bolted, not welded to provide flexibility during installation.

Removable panels shall be provided at the front of each vertical section. The arrangement shall permit cables to enter bottom and top of the enclosure and connect to their respective terminals without interference.

The assembly shall be provided with cable racks and bolting down holes.

A modular individual mounting arrangement shall be used to permit interchanging different sized device cover plates without additional drilling of structure.

Enclosure Finish for Outdoor Units: Factory- applied finish in manufacturer's standard color, undersurfaces treated with corrosion-resistant undercoating.

Enclosure Finish for Indoor Units: Factory- applied finish in manufacturer's standard gray finish over a rust -inhibiting primer on treated metal surface.

Barriers: Between adjacent switchboard sections.

Insulation and isolation for (main bus of main section) and vertical buses of feeder sections.

Space Heaters: Factory-installed electric space heaters of sufficient wattage in each vertical section to maintain enclosure temperature above expected dew point.

Space-Heater Control: (Thermostats to maintain temperature of each section above expected dew point) (Manual switching of branch-circuit protective device).

Space-Heater Power Source: (Transformer, factory installed in switchboard) (120-V external branch circuit).

Utility Metering Compartment: Fabricated compartment and section complying with utility company's requirements. If separate vertical section is required for utility metering, match and align with basic switchboard.

Bus Transition and Incoming Pull Sections: Matched and aligned with basic switchboard.

Removable, Hinged Rear Doors and Compartment Covers: Secured by for access to rear interior of switchboard.

Pull Box on Top of switchboard (if provided):

Adequate ventilation to maintain temperature in pull box within same limits as switchboard.

Set back from front to clear circuit-breaker removal mechanism. Removable covers shall form top, front and sides. Top covers at rear shall be easily removable for drilling and cutting.

Bottom shall be insulating, fire resistive material with separate holes for cable drops into switchboard.

Cable supports shall be arranged to facilitate cabling and adequate to support cables indicated, including those for future installation.

Structure and buses shall be arranged to permit future sections to be added to the left and right sides. Suitable cover plate must be provided for temporary protection. The assembly shall be vermin and rodent proof. Protection shall be to IP 41, as Standard to IEC 529 as a minimum requirement.

Paint finish shall be color light grey RAL 7032 semi glass.

Paint depth shall be 60 microns

Paint process shall be 4 stage processes of chemical spray degreasing, iron phosphate coating, automatic electro-static epoxy polyester film application and curing in a high temperature controlled oven.

The complete switchboard, after assembly shall be tested for operation under simulated service conditions to assure the accuracy of the wiring and the functioning of all equipment.

The main circuits shall be given a dielectric test of 2500 volts as required by IEC 60439-1 between live parts and ground, and between opposite polarities. The wiring and control circuits shall be given a dielectric test of 1500 volts as required by IEC 60439-1 between live parts and ground.

H.17.2.4 Busbars

Main horizontal bus bar ratings as shown on the Contractor's approved shop drawings shall be provided across the top of each structure.

All bus connections shall be bolted and clamp type terminals provided for cables.

All bus work and connections shall be accessible for inspection and maintenance purposes.

The short time with stand current shall be calculated, but not less than 50 KA rms for 1 sec.

All buses and connections of the switchboard shall consist of high conductivity copper bars mounted on heavy duty glass polyester supports to BS 159.

Bus bars insulating supports shall withstand fire and excessive heat as per IEC 695-2.1.

The bus shall be electrolytic copper of the CU ETP type (ISO 1337) and of sufficient cross-sectional area to continuously conduct rated current with a maximum average temperature rise of 50° C above the ambient temperature.

All section (vertical) and through (horizontal) bus bars shall be isolated phase from phase and phase from grounded dead metal through the use of insulating material properly applied in a complete insulation/isolation system. This system shall be in addition to the minimum UL clearances established in the basic bus design. It shall be totally independent of the bus support system so that it may be removed or replaced for inspection and maintenance without affecting the structural rigidity of the assembly.

Bus-Bar Insulation: Factory-applied, flame-retardant, tape wrapping of individual bus bars or flame-retardant, spray-applied insulation. Minimum insulation temperature rating: 105 deg. C.

Buses and Connections:

- Phase-and Neutral-Bus Material: Hard-drawn copper of 98 percent conductivity with feeder circuit-breaker line connections.
- Load Terminals: insulated, rigidly braced, silver-plated, copper runback bus extensions equipped with pressure connectors for outgoing circuit conductors. Provide load terminals for future circuit-breaker positions.
- Ground bus: ¼ by-2-inches – (6-by-50mm) minimum size and in accordance to NEC for prospective short circuit current, hard-drawn copper of 98 percent conductivity, equipped with pressure connectors for feeder and branch-circuit ground conductors. For bus way feeders, extend insulated equipment grounding cable to bus way ground connection and support cable at intervals in vertical run. A breaking strip shall be used for insulation measurement and shall be removed by using a tool.
- Contact surfaces of buses: Silver plated.

- Main Phase Buses, Neutral Buses, and Equipment Ground Buses: Uniform capacity for entire length of switchboard's main and distribution sections. Provide for future extensions from both ends.
- Isolation Barrier Access Provisions: Permit checking of bus-bolt tightness.
- Neutral Buses: 100 percent of the ampacity of phase buses, unless otherwise indicated, equipped with pressure connectors for outgoing circuit neutral cables. Bus extensions for bus way feeder neutral bus are braced.

Main Distribution Switchboard that is fed directly from the transformer shall have the following additional features:

- Neutral bus bar shall be provided with a removable solid bar link for testing purposes.
- A separate bonding strap shall be connected from the neutral bus to the switchboard frame. This bonding strap shall be located on the line side of the removable neutral link maintaining a service ground to the switchboard frame when the test link is removed.
- Any additional feature as per the Electrical Authorities requirements.

Future Devices: Equip Compartments with mounting brackets, supports, bus connections, and appurtenances at full rating of circuit-breaker compartment.

H.17.2.5 Protection And Safety

The LV switchboards shall ensure the safety of people and equipment as well as a high level of continuity of service.

Switching safety shall be procured by a mechanical system that prevents on-load disconnection.

The power circuit and the control circuit shall be separated and fully isolated.

All small wiring shall be neatly bunched and cleated in harness form, using purpose-made plastic cable ties, or shall be enclosed in purpose-made plastic small wiring trunking. Wiring cleated to metal surface shall be spaced off the metal or otherwise insulated from it. Metallic "buckle clips" shall not be used for internal wiring. Wiring to swing doors or other moveable items shall be flexible cables neatly bunched and constrained by a flexible harness.

Small wiring to which external connections have to be made shall be terminated on approved type terminal blocks which shall be easily accessible and conveniently arranged to facilitate the connection of incoming and outgoing multi-core cables. Each terminal unit shall have separate incoming and outgoing terminals and no more than one wire shall be connected to any one terminal unless the terminal is specifically designed to take more than one. Each terminal block for external wiring shall have at least 10% spare capacity with a minimum of two spare terminals. All terminal blocks shall be numbered in sequence to match the numbering on the wiring or connection diagrams.

H.17.2.6 Control And Monitoring System

The main distribution switchboards must be equipped with a monitoring system that includes:

- Power meter module (PM) at the incoming and at each outgoing (Breaker or ATS). The (PM) shall monitor voltage, currents, frequency, Cosphi, kVA, kW, etc...and must include a port RS 485 for communication.

Power meters shall combine the following functions in a single unit:

- True rms measurement up to the 31st harmonic for voltage, current, frequency, power, power factor;
- Metering of active and reactive energy;
- Indication and control via two output relays that can be assigned to power or power factor to trip alarms or initiate load shedding;
- Communications via the internal bus or a MODBUS/JBUS network.

Technical Characteristics of Measurements:

- Phase-to-neutral voltages (V1N, V2N, V3N): Yes
- Phase-to-phase voltages (U12, U23, U31): Yes
- Currents (I1, I2, I3, IN): Yes
- Frequency: Yes
- Power Factor: Yes
- Power:
- Active: Yes
- Reactive: Yes
- Energy consumed: active Yes
- Reactive Yes
- Apparent
- Reset of meters (including maxi meter)
- Assignment of output relays
- Power (active, reactive, apparent) Yes
- Demand power Yes
- Power factor Yes
- Voltages Yes
- Currents Yes

Internal bus; all modules will be connected in parallel to a terminal block. The bus RS485 will be connected to the main BMS of the project through a central unit CU (Interface or integrator). The CU will be supplied by the BMS contractor in order to ensure the transmission of all collected data by the modules inside the switchboard. The BMS will record the data on current and voltage to be used for inspection in case of failure; in addition all the collected data will be available on the BMS screen for regular supervision.

The switchboard Central Unit shall ensure:

- The collection and organization of data.
- The communication with the installation supervisor.
- The power monitoring modules shall be designed to:
- Control all types of outgoing or incoming feeders.
- Be remotely addressed.

H.17.2.7 Forms for Panel

The basic four forms according to IEC 439-1 for the assembly of switchboards and internal separation of assemblies or partitions into sub-compartment is as follow:

Form 1 No separation between bus bars, functional units and terminals for external conductors.

Form 2A Separation of the bus bars from the functional units. The terminals for external conductors do not need to be separated from the bus bars.

Form 2B Separation of the bus bars from the functional units. The terminals for external conductors are also separated from the bus bars.

Form 3A Separation of bus bars from the functional units and separation of all functional units but not their terminals for external conductors, from one another. The terminal for external conductors needs not to be separated from the bus bars.

Form 3B Separation of bus bars from the functional units and separation of all functional units from one another. Separation of terminal for external conductors from the functional units and from the bus bars but not from one another.

Form 4a Separation of bus bars from the functional units and separation of all functional units including their terminals for external conductors, from one another. The cables shall be glanded off on gland plates within the functional unit compartment.

Note: In for 3A, 3B & 4a, the main breaker and outgoing larger than 600A frame size shall be located in their own column, completely segregated from all others parts of the switchboard.

H.17.2.8 Circuit Breakers

LV AIR CIRCUIT BREAKER

The circuit breakers shall comply with IEC947.2 or corresponding standards in member countries (VDE 0660: BS 4752: UTE C63120): optional version may comply with UL/ANSI/JIS standard.

The breaking capacity performance certificates shall be available for category B to the above-mentioned standards. The test shall be carried out with a breaking performance during operation (I_{cs}) equal to the ultimate breaking capacity (I_{cu}).

All circuit breakers can be reverse fed without reduction in performance.

All breakers shall be withdrawable and motorized.

All circuit breakers shall have a rated operational voltage of 690V AC (50Hz).

The rated insulation voltage shall be 1000 V AC (50 Hz).

All circuit breakers shall fully tropicalized (T2) as standard.

The circuit breaker shall comply with the isolating function requirements of IEC 947-2 section 7.1.2.

All breakers shall be equipped with necessary contacts and control devices for connection and monitoring through Building Management System.

Minimum electrical endurance: 10000 operations

A. CONSTRUCTION

They shall be available in fixed or draw out models and in 3-poles or 4-poles versions as indicated on drawing.

The required safety clearance around the air circuit breaker may be canceled by adding protective covers. Type tests shall be achieved with the minimum safety clearance.

All air circuit breakers shall be designed to be maintained; in order to reduce maintenance, electrical endurance characteristics shall be very high. Up to 2000A, the circuit breaker shall offer an electrical endurance without servicing or maintenance (CO at $U_n = 690V$) equal to the mechanical endurance.

On 4-pole version, the neutral pole shall have the same current rating as the other poles from 800 up to 4000A and N/2 from 5000 up to 6300A.

All air circuit breakers main contact shall be encased in a reinforced polyester casing and offer double insulation from the operators on the breaker front face. The circuit breaker also shall offer total insulation of the control part with respect to the power part.

B. OPERATING MECHANISM

The operating mechanism shall be of the O.C.O stored energy spring type with a closing time of less than or equal to 80 ms.

There shall be 2 types of spring charging, either:

- Hand charged spring where the springs are wound only by hand or:
- Motor charged spring, where the springs are automatically charged by an electric motor. The maximum time to charge the springs shall not exceed 4 seconds. It shall also be possible to charge the springs manually.

C. A R C C HUTES

Arc chutes shall be common on the whole range and removable on site to allow inspection of arc chutes and main contact.

i) Drawout Mechanism

1) General

The draw out operation shall be possible through a closed door.

Three positions of the moving part shall be possible: 1. Connected position - all auxiliary and main circuits engaged. 2. Test position - all auxiliary circuits engaged all main circuits disconnected. 3. Isolated position - all circuits disconnected.

2) Safety Requirements

A door interlock shall be provided so that it shall not be possible to open the door until the air circuit breaker moving part is in the disconnected position.

Insulated safety shutters shall be provided over the incoming and outgoing main circuits and over the auxiliary circuits. An interlocking shall be provided to prevent insertion of a circuit breaker having a rating higher than the current range the fixed part, into that fixed part.

The racking handle shall be stowed on the air circuit breaker in such a manner as to be accessible without defeating the door interlocking.

The safety perimeter shall be reduced to zero for the draw out version above and to the sides of the A.C.B.

ii) Electrical Auxiliaries

All electrical auxiliaries including the motor spring charging mechanism shall be field adaptable without adjustment or the necessary for any tool (except a screwdriver). They shall be fitted into a compartment which under normally loaded conditions has no metalwork energized from the main poles exposed with it. Any adaptation carried out thus shall not increase the breaker volume.

It shall be possible connect all auxiliary wiring from the front face of the air circuit breaker, this wiring shall be taken through a set of disconnecting contact, so that all auxiliary wiring is automatically disconnected in the isolated position.

D. M E C H A N I C A L I N D I C A T O R S

Mechanical indication on the front of the air circuit breaker shall be provided to indicate the following: 1. Main contacts closed "ON". 2. Main contacts open "OFF". 3. Springs charged. 4. Springs discharged. 5. Circuit breaker in "connected" position (draw out only). 6. Circuit breaker in "test" position (draw out only). 7. Circuit breaker in "disconnected" position (draw out only).

All indicators must be clearly visible.

E. CONTROL AND PROTECTION

i) General Requirements

The over current relay shall be a solid state type

It shall be microprocessor based and use digital programming techniques for highest protection accuracy.

And be integrated as part of the circuit breaker The sensors and the wiring shall be integrated within the case. The over current relay shall be self powered. The current sensors shall be located within the case of the circuit breaker; they shall be air core type to ensure: Accurate measurement from 200 A up to 75 kA. The highest discrimination up to the circuit breaker electro-dynamical withstand even for the instantaneous protection

The over current relay shall have a wide adjustment range to allow flexibility of setting on site. The trip unit shall measure the true RMS value of any waveform of current.

The control unit shall be equipped with a push to reset mechanical indicator, for anti-pumping function.

The control unit may communicate with other equipment on a communication BUS.

ii) Characteristics

Long time protection (LT). Adjustable (in steps of 4%) from 0,4 to 1 of the sensor rating. Time delay adjustable from 15 to 480 seconds (at 1.5 times the long time setting)

Short time protection (ST) Adjustable (in steps of 4%) from 0,4 to 1 of the sensor rating. Time delay adjustable from instantaneous to 0.4 seconds.

Time inverse characteristics (12t) may be switched in to improve discrimination.

Instantaneous (INST) N and H types, adjustable from 2 times up to:

At least 20 times the rated current for sensor rating up to 2000A

At least 10 times the rated current for sensor rating above 2000A

L type, adjustable from 2 times up to at least 6 times the rated current.

iii) Control functions

In order to optimize the operation, maintenance and monitoring of the breaker in complete safety the following control items shall be supplied as standard as an integral part of the control unit: Local over current LED indication with 2 levels - LED steady or flashing - on the front face and one volt free out contact shall indicate as a pre trip alarm. Two NO and two NC output contacts plus one CO fault trip contact (SDE) shall be available. Thermal memory:

The control unit shall optimize the protection of the equipment or the circuit conductors in the event of repeated overloads or faults by using thermal integration to memorize temperature rises.

iv) Safety:

Internal overheating of the control unit shall be signaled by a self monitoring alarm.

v) Options

Without increasing the volume it shall be possible to combine the following functions into the circuit breaker control unit.

Load monitoring and control

Two adjustable settings with output contacts shall be available. These settings to be related to the long time protection setting.

Zone selective interlocking for the short time and earth fault protection

Earth fault protection

Remote indication of one particular fault as selected by a switch on front face.

Fault trip indication- indicating the element (long time, short time/instantaneous, earth fault protection of supplied) that has caused the circuit breaker to trip, indicated locally by a LED.

vi) Measurement: A digital display ammeter shall indicate the RMS value of the circuit breaker phase currents with a switch on the front face for selection. A bar graph shall display the load indication of each phase. The highest value of phase current shall be stored and displayed on demand.

vii) Communication (as required):

The data or action needed for the control and indication functions shall be available on a BUS via a specific modular system i.e.: Circuit breaker state. Control unit settings. Cause of circuit breaker trip. Circuit breaker operation.

viii) Energy Measurement (as required)

In order to optimize the network energy management, the parameters:

Voltage, frequency, active and reactive power and energy and power factor shall be displayable on a digital display on the front face. The voltage measurement shall be achieved without external transformers.

All of this data shall be available on a BUS.

ix) Data Transmission (as required):

The data needed for the control and indication functions shall be available on a BUS. Circuit breaker state. Control unit settings value. Cause of circuit breaker trip and current interrupted. Phase current values, voltage value, and power value. Thermal memory status, self monitoring output status. Circuit breaker operation.

x) Neutral Protection

On four-pole circuit breakers, neutral protection shall be ensured.

xi) Programmable alarms:

Depending on the thresholds and time delays set the control unit shall monitor currents and voltage, power, frequency and the phase sequence. Each threshold overrun shall be signaled remotely via Communication System. Each threshold overrun may be combined with tripping (protection) or an indication carried out by an programmable contact (alarm).

xii) Load shedding and reconnection:

Load shedding and reconnection parameters shall be carried out by a supervisor via the programmable contacts.

xiii) Histories and maintenance indicators

The last ten trips and alarms shall be recorded in history files. Maintenance indications (contact wear, operation cycles, etc..) shall be recorded for local access.

H I G H R A T I N G M O L D E D C A S E C I R C U I T B R E A K E R S (A B O V E 8 0 0 A)

A. General

The high rating MCCB shall comply with IEC 947-2 or corresponding standards in member countries (VDE 0660; BS 4752; UTE C63120): they may as an alternative comply with UL/JIS standards.

The breaking capacity performance certificates shall be available for the category A&B to the above- mentioned standards. The test shall be carried out under the breaking performance during operation (I_{cs}) and under the admissible short time withstand (I_{cw}) equal to 50% of the ultimate breaking capacity (I_{cu}).

All breakers shall be equipped with necessary auxiliary contacts and controls for connection and monitoring through Building Management System.

The MCCB shall have a rated operational voltage of 690V AC (50 Hz).

The rated insulation voltage shall be 750V AC (50 Hz).

The MCCB shall be designed for horizontal or vertical mounting without any adverse effect on electrical performance.

It shall be possible to reverse feed the breaker without reduction in performance up to 500V AC.

The breaker shall be maintenance free and fully tropicalized (T2).

It shall either be 3 poles or 4 poles (switched neutral).

The MCCB shall be of circuit breaker disconnecter type.

Otherwise MCCB shall have a minimum rms symmetrical interrupting capacity of 35 KA rms.

B. Construction

The operating mechanism of the circuit breaker shall be of the trip free type, quick make and quick break design. All mechanical components of the breaker shall be enclosed in an insulated casing.

The trip unit shall be of the solid state type energized by internally mounted/current transformers. It shall not require any external power supply to operate the tripping mechanism. The trip unit shall be interchangeable.

C. Characteristics

The solid state protection unit shall have as required.

Long time protection adjustable from 0.5 to 1 times sensor rating

Short time protection.

Adjustable from 3 to 6 times the setting made on the long time protection

Time delay (when required) adjustable from instantaneous to 0.225s.

Instantaneous

Threshold set at 35 kA.

Earth fault protection (when required).

Adjustable from 0.2 to 0.5 times the setting made on the long time protection

Time delay from instantaneous to 0.3s.

The standard operating mechanism shall be constructed so that the handle of the circuit breaker indicates the true position of the contacts to ensure a positive break indication.

Where required, motor operated mechanism, shunt trip, under voltage release, auxiliary switches up to four changeover contacts and a tripped signal contact shall be provided. Each of these units shall incorporate a pre-wired terminal strip, which is accessible from the front of the breaker without removing the cover.

D. Operation

If required, the breaker shall be provided with the facility for padlocking or key locking in the open position.

E. Characteristics for Control Units of MCCB 800A and Above

i) Protection:

Protection thresholds and delays shall be set using the adjustment dials. The selected values are momentarily displayed on the screen, in amperes and in seconds.

a) Overload protection:

True rms long-time protection.

Thermal memory: thermal image before and after tripping.

b) Short-circuit protection:

Short-time (rms) and instantaneous protection.

Selection of I 2 t type (ON or OFF) for short-time delay.

c) Earth-fault protection:

Residual or source ground return earth fault protection.

Selection of I 2 t type (ON or OFF) for delay.

d) Residual earth-leakage protection (Vigi):

Operation without an external power supply and shall be protected against nuisance tripping.

e) Neutral protection:

On four-pole circuit breakers, neutral protection shall be set using a three-position switch.

ii) Zone selective interlocking (ZSI):

A terminal block may be used to interconnect a number of control units to provide total discrimination for short-time and earth-fault protection, without a delay before tripping.

iii) Overload Alarm:

A red alarm LED goes on when the current exceeds the long-time trip threshold.

MOLDED-CASE CIRCUIT BREAKERS (FROM 100 TO 630A)

A. General

The molded-case circuit breakers shall comply with IEC 947-1 and 947-2 standards or with the corresponding standards applicable in the member countries (VDE 0660, BS 4752, NF EN 60 947-1/2):

- They shall be of category A with a rated service breaking capacity (Ics) equal to the ultimate breaking capacity (Icu) on all the operation voltage range for the ratings up to 250A, up to 500V for the greater ratings.
- They shall have a rated operational voltage of 690 V AC (50Hz.).
- They shall have a rated insulation voltage of 750 V AC (50Hz.).

- They shall be suitable for isolation, as defined by IEC 947-2, § 7-27.

Production site organization shall be certified to comply with ISO 9002 standard.

All breakers shall be equipped with necessary auxiliary contacts and controls for connection and monitoring through Building Management System.

The Molded-case circuit breakers shall be available in fixed or plug-in/withdrawable versions as well as in 3- pole and 4- pole versions as shown on the Contractor's approved shop drawings. For plug-in/withdrawable versions, a safety trip shall provide advanced opening to prevent connection and disconnection of a closed circuit breaker.

The Molded-case circuit breakers shall be designed for both vertical and horizontal mounting, without any adverse effect on electrical performance. It shall be possible to supply power either from the upstream or downstream side.

The Molded -case circuit breakers shall provide class II insulation (according to IEC 664 standard) between the front and internal power circuits.

The minimum short circuit interrupting capacity shall be:

- 25 KA rms for breakers up to 150 A frame.
- 35 KA rms for breakers with 250 A frame and above.

B. Construction, Operation, Environment

For maximum safety, the power contacts shall be insulated in an enclosure made of a thermosetting material from other functions such as the operating mechanism, the case, the trip unit and auxiliaries.

The operating mechanism of the case-case circuit breakers shall be of the quick-make, quick-break type with fault tripping overriding manual operation. All poles shall operate simultaneously for circuit breaker opening, closing and tripping.

The molded case circuit breakers shall be actuated by a toggle or handle that clearly indicates the three positions: ON, OFF and TRIPPED.

In order to ensure suitability for isolation complying with IEC 947-2 § 7-27:

- The operating mechanism shall be designed such that the toggle or handle can only be in OFF position (O) if the power contacts are all actually separated.
- In OFF position, the toggle or handle shall indicate the isolation position.

Isolation shall be provided by a double break on the main circuit.

The Molded -case circuit breakers shall be to receive a device for locking in the " isolated " position, with up to 3 padlocks.

The Molded -case circuit breakers shall be equipped with a " push to trip " button in front to test operation and the opening of the poles.

The circuit breaker rating, the " push to trip " button, outgoing circuit identification and the contact position indication must be clearly visible and accessible from the front, through the front panel or the door of the switchboard.

C. Current Limiting, Discrimination, Endurance

The Molded -case circuit breakers shall be capable of greatly limiting currents. For short-circuits, the maximum thermal stress $I^2 t$ shall be limited to:

- 10 6 A 2 s for rating up to 250 A.
- 5 x 10 6 A 2 s for ratings between 400 A and 630 A.

The Molded -case circuit breakers shall comprise a device, designed to trip the circuit-breaker in the event of high-value short-circuit currents. This device shall be independent of the thermal-magnetic or electronic trip unit.

The Molded -case circuit breakers, the current ratings of which are identical with the ratings of their trip units, shall ensure discrimination for any fault current up to at least 35 kA rms, with any downstream circuit-breaker having a current rating less or equal to 0.4 times that of the upstream circuit-breaker.

The electrical endurance of the case-case circuit breakers, as defined by IEC 947-2 standard, shall be at least equal to 3 times the minimum required by the standard.

D. Auxiliaries and Accessories

It shall be possible to equip the case-case circuit breakers with a motor mechanism for electrically controlled operation. An "auto/manual" switch in front shall, when set to the "manual" position, lock out electrical control; remote indication of "manual" or "auto" mode shall be possible.

Closing shall take place in less than 80 ms.

Following tripping due to electrical faults (overloads, short-circuit, earth fault), remote reset shall be inhibited.

It shall however be possible if opening was initiated by a voltage release.

The operating mechanism shall be of the stored-energy type only.

The addition of a motor mechanism or a rotary handle shall in no way affect circuit breaker characteristics:

- Only three stable tripping mechanism positions (ON, OFF and TRIPPED) shall be possible with the motor mechanism.
- Suitability for isolation shall be provided by positive contact indication (ON and OFF) in front of the motor mechanism module.

The case-case circuit breakers shall be designed to enable safe on-site installation of auxiliaries such as voltage releases (shunt and under voltage releases) and indication switches as follows:

- They shall be separated from power circuits
- All electrical auxiliaries shall be of the snap-in type and fitted with terminal blocks
- All auxiliaries shall be common for the entire range
- Auxiliary function and terminals shall be permanently engraved on the case of the circuit breaker and the auxiliary itself.
- The addition of auxiliaries shall not increase the volume of the circuit breaker.

The addition of a motor mechanism module or a rotary handle, etc., shall not mask or block device settings.

It shall be possible to assemble earth fault protection case-case circuit breakers by adding a residual current device (RCD) directly to the circuit breaker case. The resulting device shall

- Comply with appendix B of IEC 947-2 standard
- Be immunized against nuisance tripping as per IEC 255 and IEC 801-2 to -5 standards
- Be capable of working normally down to -25 °C ambient temperature.

- Operate without and auxiliary power supply, i.e. it shall be capable of operating normally on any 2-phase or 3-phase power network with a voltage between 200 V and 440 V, and of tripping the circuit-breaker even in event of voltage dips down to 80V.

It shall be possible to equip the case-case circuit breakers with devices indicating faults without tripping the circuit breaker.

E. Protection Functions for MCCB

1-General Recommendations for MCCB up to 160A frame size

Molded-case circuit breakers with ratings up to 160 A frame shall be equipped with of:

- Thermal-magnetic (thermal for overload protection and magnetic for short-circuit protection).

It shall be possible to interchange thermal magnetic trip with electronic trip unit when needed for selectivity or coordination between upstream and downstream breaker electronic trip unit shall be offered at no extra cost if needed for coordination.

- Electronic.

Molded-case circuit breakers with ratings equal and over 250 A shall be equipped with electronic trip units.

The trip units shall not augment overall circuit breaker volume.

Electronic trip units shall comply with appendix F of IEC 047-2 standard (measurement of rms current values, electromagnetic compatibility, etc.).

All electronic components shall withstand temperatures up to 125 °C.

Electronic and thermal-magnetic trip units shall be adjustable and it shall be poto fit lead seals to prevent unauthorized access to the settings.

Protection settings shall apply to all circuit breaker poles.

Thermal-Magnetic Trip Units (Up to 150A)

Characteristics:

- Adjustable thermal protection,

- Fixed magnetic protection for current ratings up to 200 A

- Adjustable (from 5 to 10 times the current rating) for current ratings greater than 200A.

It shall be possible to ensure neutral protection. The tripping threshold shall be equal to that of the phases or to a reduced value (generally half of that of the phases).

2- Electronic Trip Units (For all breakers rated 250A)

Characteristics:

Over load protection:

True rms long-time protection with an adjustable threshold.

Long time protection (TL)

- Selectable Ir threshold with forty-eight settings from 40 to 100% of the trip unit rating.

Short time protection (ST)

- 1m threshold shall be adjustable from 2 to 10 times the thermal setting I_r ,
- The time delay shall be fixed at 40 ms,

Instantaneous protection

- The threshold shall be fixed (between 12 and 19 times I_n , depending on the rating)

Four-pole devices shall be equipped with a 3-position setting for neutral protection:

Neutral not protected - neutral tripping threshold equal to half the phase value - neutral threshold equal to the phase value.

Unit shall be equipped with Modbus communication (RS 485) port.

A LED on the front shall indicate the percent load: port or port suitable for internal communication bus of vendor.

Load monitoring function

The following monitoring functions shall be integral parts of electronic trip units:

LED for load indication, lighted above 95% of I_r , flashing above 105% of I_r .

A test connector shall be installed for checks on electronic and tripping mechanism operation using an external device.

Universal Electronic Trip Units (above 250A and Greater)

3-ELECTRONIC TRIP UNITS FOR 400A AND 630A FRAME SIZE MCCB

i)Protection:

The protection functions shall be set using the adjustment dials.

a) Overload protection

Long-time protection with adjustable threshold and tripping delay: • I_o base setting (6 position dial from 0.5 to 1) • I_r fine adjustment (8-position dial from 0.8 to 1).

b) Short circuit protection:

Short-time and instantaneous protection: • Short-time protection with adjustable pick-up and tripping delay, with or without constant $I^2 t$ • Instantaneous protection with adjustable pick-up. • Earth fault protection T.

ii) Overload LED (% I_r)

A LED on the front shall indicate the percent load: • When ON, the load is > 90% of I_r setting. • When flashing, the load is > 105% of I_r setting.

iii) Fault indications:

A LED shall signals the type of fault: • Overload (long-time protection) or abnormal internal temperature (> I_r). • Short-circuit (short-time protection) or instantaneous (> I_{sd}) • Earth fault (if earth-fault-protection option installed) (> I_g) • Microprocessor malfunction.

The unit shall be Battery powered. Spare batteries shall be supplied. The LED indicating the type of fault goes OFF after approximately ten minutes to conserve battery power. The information shall be stored in memory and the LED can be turned back ON by pressing the battery/LED test pushbutton. The LED automatically goes OFF and the memory is cleared when the circuit breaker is reset.

Unit shall be equipped with Modbus Communication port 485 or port suitable for internal communication bus of vendor.

Load monitoring function

A load monitoring function shall be an integral part of universal trip units, indicating four load levels (60%, 75%, 90% and 105%) by LEDs, (flashing LED for 1.5%)..

4- Motor Protection (up to 37kW)

A. General

Motor protection against the short-circuit shall be achieved by motor circuit-breakers of molded case type; the combination with control-command devices shall be of type-2 as defined by the IEC standards 947-4.1.

The motor circuit breakers shall comply with IEC standards 957-1 and 957-2 or with corresponding standard applicable in the member countries (VDE 0660, BS 4752, NF EN 60 947-1/2):

- They shall be of category A with a rated service breaking capacity (Ics) equal to the ultimate breaking capacity (Icu).
- They shall have a rated operational voltage of 690 V AC (50 Hz.).
- They shall have a rated insulation voltage of 750 V AC (50 Hz.).
- They shall be suitable for isolation, as defined by IEC 947-2, § 7-27.

'Production site organization shall be certified to comply with ISO 9002 standard.

The motor circuit breakers shall be easily installable in the motor control-command modules. For that, the size characteristics, especially the width, shall be much closed to the other motor control-command devices ones.

The motor circuit breakers shall be designed for both vertical and horizontal mounting, without any adverse effect on electrical performance. It shall be possible to supply power either from the upstream or downstream side.

The motor circuit breakers shall provide class II insulation (according to IEC 664 standard) between the front and internal power circuits.

B. Construction, Operation, Environment

For maximum safety, the power contacts shall be insulated in an enclosure made of a thermosetting material from other functions such as the operating mechanism, the case, the trip unit and auxiliaries.

The operating mechanism of the case-case circuit breakers shall be of the quick-make, quick-break type with fault tripping overriding manual operation. All poles shall operate simultaneously for circuit breaker opening, closing and tripping.

The molded case circuit breakers shall be actuated by a toggle or handle that clearly indicates the three positions: ON, OFF and TRIPPED.

In order to ensure suitability for isolation complying with IEC 947-2 § 7-27:

- The operating mechanism shall be designed such that the toggle or handle can only be in OFF position (O) if the power contacts are all actually separated.
- In OFF position, the toggle or handle shall indicate the isolation position.

Isolation shall be provided by a double break on the main circuit.

The case-case circuit breakers shall be to receive a device for locking in the " isolated " position, with up to 3 padlocks.

The case-case circuit breakers shall be equipped with a " push to trip " button in front to test operation and the opening of the poles.

The circuit breaker rating, the " push to trip " button, outgoing circuit identification and the contact position indication must be clearly visible and accessible from the front, through the front panel or the door of the switchboard.

The motor circuit breakers shall have a very high current limiting; the electrical endurance of the case-case circuit breakers, as defined by IEC-947-2, shall be at least equal to 5 times the minimum required by the standard.

C. Auxiliaries and Accessories

It shall be possible to equip the motor circuit breakers with a direct or extended rotary handle; the addition of a rotary handle shall in no way affect circuit breaker characteristics:

- Positive indication of the 3 contact positions (ON, OFF and TRIPPED).
- Suitability for isolation shall be provided even in the case of extended rotary handle.
- The addition of a rotary handle shall not mask or block device settings.

On motor circuit breakers equipped with a rotary handle, the addition of an early-break switch shall be done easily.

The motor circuit breakers shall be designed to enable safe on-site installation of auxiliaries such as voltage releases (shunt and under voltage releases) and indication switches as follows:

- They shall be separated from power circuits
- All electrical auxiliaries shall be of the snap-in type and fitted with terminal blocks
- All auxiliaries shall be common for the entire range
- Auxiliary function and terminals shall be permanently engraved on the case of the circuit breaker and the auxiliary itself.
- The addition of auxiliaries shall not increase the volume of the circuit breaker.

D. Protection Functions

The motor circuit breakers shall be equipped with magnetic trip unit for short-circuit protection; protection settings shall apply to circuit breaker poles.

Characteristics:

- Adjustable magnetic protection with settings from 6 to 14 times the nominal rating of the device,
- The magnetic set up button shall be equipped with an adjustable protection stop in order to allow the setting range to be reduced.

E. Combination Function

In order to well protect the motor starters, the motor circuit breakers shall: Comply with type-2 co-ordination according to IEC 947-4.1 for the combination with the other control- command devices,

Have compulsory type-2 co-ordination tables, which have been tested in laboratory;

However, the combination tables shall also indicate for each motor rating:

The circuit-breaker type and set up characteristics,

The contactor type,

The thermal relay type with its setting range.

MINIATURE CIRCUIT BREAKERS (FROM 5 UP TO 100A)

A. General

MCB shall comply with IEC 157-1 or IEC 947-2, BS 3871 Part 1.

MCB shall have C curve characteristics.

MCB shall be plug-in bus bar mounted type available in one, two, three or four poles version.

The breaking capacities of the MCB's shall be at least equal to the prospective fault level at the point of the distribution system where they are installed.

Cascading with upstream breaker based on different time characteristics response shall not permitted. Only current limiting protection upstream shall be permitted.

MCB can be reverse fed without reduction in performance.

MCB shall have minimum rms symmetrical interrupting capacities equal to 9 KA.

B. Construction

The operating mechanism shall be mechanically trip free from the operating handle so as to prevent the contacts from being held closed against short circuit and overload conditions. It shall be of the "automatic resetting type".

The individual operating mechanism of each pole of a multi-pole MCB shall be directly linked within the MCB casing and not by the operating handles.

The operating handle shall be of the toggle type with possibility of padlocking facility and rotary handle.

Each pole shall be provided with bi-metallic thermal element for overload protection and magnetic element for short circuit protection. Current discrimination tables shall be provided for each rating of breaker.

Terminals shall be of the tinner (IP20) in order to minimize the risk of direct contact.

EARTH LEAKAGE RELAY WITH SEPARATE SENSOR

A. General

The relays shall comply with IEC 755 or corresponding standards (UTE C60 130, VDE 664, NFC 61 141).

The relays shall be protected against nuisance tripping caused by switching surges or by lightning surges (^).

The relays shall be of solid state type (mechanical type shall be not accepted).

The relays shall be able to operating in the presence of fault currents with DC components: they shall be of class A (relays sensitive to pulsed residual currents).

The relays shall be equipped with a pre-alarm setting; this pre-alarm setting value shall be equal to half the alarm setting value.

B. Operating

The different ratings in a given range may be obtained without changing the type of sensor.

The relays shall be adjusted in discreet steps for sensitivity adjustment and time-delay adjustments (continuous adjustment shall be not accepted). These steps may be fully discriminated.

The sensitivity shall be adjustable using a 24 position fine control switch.

The time delay, from instantaneous to 1 s, shall be adjustable using an 8 position switch.

The relays shall be equipped with a pre-alarm setting; this pre-alarm setting value shall be equal of half the alarm setting value.

C. Construction

The size of the relays shall be compact (maximum 72 mm wide).

The relays shall be suitable for mounting on symmetrical DIN rail horizontally or vertically.

The range of associated toroidal transformer shall be of the closed type with an inside diameter of 30 to 300 mm an open toroidal transformer range shall be available.

The smaller sizes of toroids (< 50 mm) may be installed directly on the relay.

D. Safety

The relays shall be equipped with:

- One changeover fails safe output contact without latching for the pre-alarm setting.
- One changeover normal output contact with or without latching for the alarm setting.

A continuity of measurement circuit should be provided to confirm break on the current transformer relay link.

The relays shall be equipped with local indication using LED's:

Green = power supply; red = pre-alarm; red = alarm.

H.17.2.9 Instrumentation

Instrument Transformers:

- Potential Transformers: Secondary voltage rating of 220 V and accuracy class of 0.3 with burdens of W, X and Y as per NEMA.
- Current transformers: Ratios shall be as indicated with accuracy class and burden suitable for connected relays, meters, and instruments.
- Control-Power Transformers: Dry type, mounted in separate compartments for units larger than 3KV.
- Current Transformers for Neutral and Ground-Fault Current Sensing: Connect secondary to ground over current relays, meters, and instruments.

Multifunction Digital-Metering Monitor: Microprocessor-based unit suitable for three – or four-wire systems and with the following features:

- Switch-selectable digital display of the following values with maximum accuracy tolerances as indicated: i) Phase Currents, Each Phase: Plus or minus 1 percent. ii) Phase-to-Phase Voltages, Three Phase: Plus or minus 1 percent. iii) Phase-to-Neutral Voltage, Three Phase: Plus or minus 1 percent. iv) Megawatts: Plus or minus 2 percent. v) Megavars: Plus or minus 2 percent. vi) Power Factor: Plus or minus 2 percent. vii) Frequency: Plus or minus 0.5 percent. viii) Megawatt Demand: Plus or minus 2 percent; demand interval programmable from 5 to 60 minutes. ix) Accumulated Energy, Megawatt hours: Plus or minus 2 percent. Accumulated values unaffected by power outages up to 72 hours.
- Mounting: Display and control unit flush or semiflush mounted in instrument compartment door.

Ammeters, Voltmeters, and Power-Factor Meters: ANSI C39.1.

- Meters: 4 inch (100-mm) diameter or 6 inches (150 inch) square, flush or semi flush, with ant parallax 250-degree scales and external zero adjustment

- Voltmeters: Cover an expanded-scale range of nominal voltage plus 10 percent

Instrument Switches: Rotary type with off position.

- Voltmeter Switches: Permit reading of all phase-to-phase voltages and, where a neutral is indicated, phase-to-neutral voltages.
- Ammeter Switches: Permit reading of current in each phase and maintain current-transformer secondaries in a closed-circuit condition at all times.

Feeder Ammeters: 2-1/2-inch- (64-mm-) minimum size with 90- or 120-degree scale. Meter and transfer device with an off position

G Watt-Hour Meters: Flush or semi flush type, rated 5 A. 120 V, 3 phase, 3 wire, with 3 elements, 15- minute-indicating-demand register, and provision for testing and adding pulse initiation.

Recording Demand Meter: Usable as totalizing relay or as indicating and recording maximum-demand meter with 15-minute interval. Meter shall count and control a succession of pulses entering two channels. House in draw out, back-connected case arranged for semi flush mounting.

H.17.2.10 Control Power

Control Circuits: 220 V, supplied through secondary disconnecting devices from control-power transformer.

Electrically Interlocked Main and Tie Circuit Breakers: Two control-power transformers in separate compartments, with interlocking relays, connected to the primary side of each control-power transformer at the line side of the associated main circuit breaker. 220- V secondaries connected through automatic transfer relays to ensure a fail-safe automatic transfer scheme.

Control-Power Fuses: Primary and secondary fuses for current-limiting and overload protection of transformer and fuses for protection of control circuits.

Control Wiring: Factory installed, with bundling, lacing, and protection included Provide flexible conductors for 6mm.sq and smaller, for conductors across hinges, and for conductors for interconnections between shipping units.

H.17.2.11 Accessory Components and Features

Furnish accessory set including tools and miscellaneous items required for over current protective device test, inspection, maintenance, and operation.

Furnish portable test set to test functions of solid-state trip devices without removal from switchboard Include relay and meter test plugs suitable for testing switchboard meters and switchboard class relays.

Furnish one portable, floor-supported, roller-based. Elevating carriage arranged for movement of circuit breakers in and out of compartments for present and future circuit breakers.

Furnish overhead circuit-breaker lifting device, mounted at top front of switchboard, with hoist and lifting yokes matching each draw out circuit breaker.

Spare-Fuse Cabinet: Suitably identified, wall-mounted, lockable, compartmented steel box or cabinet Arrange for wall mounting.

Fungus Proofing: Permanent fungicidal treatment for switchboard interior, including instruments and instrument transformers.

H.17.2.12 Identification

Mimic Bus: Continuously integrated mimic bus factory applied to front of switchboard Arrange in single-line diagram format, using symbols and letter designations consistent with final mimic-bus diagram. Coordinate mimic-bus segments with devices in switchboard sections to which they are applied. Produce a concise visual presentation of principal switchboard components and connections.

Presentation Media: Painted graphics in color contrasting with background color to represent bus and components complete with lettered designations.

H.17.2.13 Labels

Each incoming and outgoing circuit on the switchboard shall be clearly identified on the front panel by means of an engraved label bearing black letters on a white background. The labels shall be of plastic engraving laminate with lettering not less than 5mm high and shall be secured to the panel front with instrument headed machine screws. Where rear access is available label shall also be fixed to the rear panels.

Warning labels shall be fitted in all places where the removal of covers or access panels may expose live equipment operating at a pressure exceeding 250V between phases or to earth. Warning labels shall be of plastic engraving laminate with red lettering on a white background, and shall bear the inscription "DANGER – "LIVE PARTS OVER 250 V" in letters not less than 10mm high.

All equipment and apparatus, both inside and outside the switchboard, including instruments, meters, and relays, which is not clearly identified by integral labeling, shall be adequately labeled in the manner described above for front-of-panel circuit labels

H.17.3 Execution

H.17.3.1 Protection

Apply manufacturer's written instructions.

H.17.3.2 Examination

Examine elements and surfaces to receive switchboards for compliance with installation tolerances and other conditions affecting performance.

Proceed with installation only after unsatisfactory conditions have been corrected.

H.17.3.3 Installation

Installation of LV power distribution boards / switchboards shall be in accordance with manufacturer's written instructions and shall comply fully with the requirements of NEC, IEC, and recognized industry practices.

Supply all material for construction of base in correct location, level and true grade and connect all incoming and outgoing cables, bus-ducts, etc.

Install the switchboards on to bases using appropriate lifting equipment to ensure that no damage occurs. When correctly located, the unit shall be anchored in position and tested before and after connecting the incoming and outgoing cables, but-ducts, etc.

Check ratings of all circuit protection devices and fill out the circuit directory card upon completion of installation work.

Install and anchor switchboards level on concrete bases, 4-inch (100-mm) nominal thickness. Concrete base is specified in Section "Electrical Supports and Seismic Restraints," and concrete materials and installation requirements as specified.

- Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch (450-mm) centers around full perimeter of base.
- For switchboards, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.
- Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
- Install anchor bolts to elevations required for proper attachment to switchboards.

Temporary Lifting Provisions: Remove temporary lifting eyes, channels, and brackets and temporary blocking of moving parts from switchboard units and components.

Operating Instructions: Frame and mount the printed basic operating instructions for switchboards, including control and key interlocking sequences and emergency procedures. Fabricate frame of finished wood or metal and cover instructions with clear acrylic plastic. Mount on front of switchboards.

Install over current protective devices, transient voltage suppression devices, and instrumentation. 1. Set field-adjustable switches and circuit-breaker trip ranges. F. Install spare-fuse cabinet.

H.17.3.4 Identification

Identify field-installed conductors, interconnecting wiring, and components; provide warning signs as specified in Section "Electrical Identification."

Switchboard Nameplates: Label each switchboard compartment with engraved metal or laminated-plastic nameplate mounted with corrosion-resistant screws.

H.17.3.5 Field Quality Control

Testing Agency: Owner will engage a qualified testing and inspecting agency to perform field tests and inspections and prepare test reports.

Perform the following field tests and inspections and prepare test reports:

- Perform each electrical test and visual and mechanical inspection stated in IEC 439-1 as appropriate. Certify compliance with test parameters.
- Correct malfunctioning units on-site, where possible, and retest to demonstrate compliance; otherwise, replace with new units and retest.
- Perform the following infrared scan tests and inspections and prepare reports:

a. Initial Infrared Scanning: After Substantial Completion, but not more than 60 days after Final Acceptance, performs an infrared scan of each switchboard Remove front and rear panels so joints and connections are accessible to portable scanner.

b. Follow-up Infrared Scanning: Perform an additional follow-up infrared scan of each switchboard 11 months after date of Substantial Completion.

c. Instruments, Equipment, and Reports:

• Use an infrared scanning device designed to measure temperature or to detect significant deviations from normal values. Provide calibration record for device. • Prepare a certified report that identifies switchboards included and that describes scanning results. Include notation of deficiencies detected, remedial action taken and observations after remedial action. • Prior to energization of main and sub-main LV power distribution boards / switchboards, following tests shall be carried out: i. Testing of all accessible bolted connections of busbars, devices and terminations to manufacturer's torque specifications. ii. Testing of insulation resistance. iii. Testing of electrical continuity / short circuits of the circuits. iv. Current injection testing of all circuit breakers and protective devices. v. Ratio tests of all current transformers. vi. High voltage /pressure test with all isolators closed and power fuses fitted but having all control circuits disconnected, for one minute with a voltage of 2kV across the following points:

- Phase to phase.
- Phase to neutral.
- Phase to earth.
- Neutral to earth.
- Subsequent to wire and cable hook-ups, energize the LV power distribution boards and demonstrate functioning in coordinate with the requirements. Check whether all outgoing are connected as per load schedules. Record changes in the schedule for final as-built, if acceptable to the Engineer.
- Approval of tests and test certificates that may be given shall not relieve the contractor of the obligation to supply the complete equipment in accordance with the requirements of the Specification, Schedules and Drawings.

H.17.3.6 Adjustments

Adjust circuit breakers, protective relays and other control devices to provide adequate over current protection and selective tripping with downstream devices in accordance with short circuit and protection coordination study and after proper coordination with protection settings of Electricity Supply Authority.

H.17.3.7 Cleaning

On completion of installation, inspect interior and exterior of switchboards.. Remove paint splatters and other spots. Vacuum dirt and debris; do not use compressed air to assist in cleaning; Repair exposed surfaces to match original finish.

H.17.3.8 Demonstration

Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain switchboards, overcurrent protective devices, instrumentation, and accessories. Refer to Section "Demonstration and Training."

H.17.3.9 Accessories

All the rooms for main LV Power Distribution Boards / switchboards shall be equipped with all accessories necessary to form a complete installation including, but not be limited to, the following operating and safety accessories:

- 1 pair of insulating gloves.
- 1 rubber mat 10 mm thick x 1000mm wide and extending the full length of the equipment.
- 1 notice and safety instruction chart including first aid chart for electric shock.
- 1 set of spare control circuit fuses.

Any other equipment necessary to comply with the standards

H.18. PANEL BOARDS

H.18.1 General

H.18.1.1 Related Documents

General provisions of the Contract, including General and Supplementary Conditions and Specification Sections, apply to this Section.

H.18.1.2 Summary

This Section includes the following:

- Distribution panel boards (DB) and Power Panel board (PP).
- Lighting and appliance branch-circuit panel boards (LP).
- Motor Starter Panel (MSP)
- Pump control panel (PCP)

H.18.1.3 Submittals

Product Data: For each type of panel board, over current protective device, transient voltage suppression device, accessory, and component indicated. Include dimensions and manufacturer's technical data on features, performance, electrical characteristics, ratings, and finishes.

Shop Drawings: For each panel board and related equipment.

1. Dimensioned plans, elevations, sections, and details. Show tabulations of installed devices, equipment features, and ratings. Include the following:
 - Enclosure types and details.
 - Bus configuration, current, and voltage ratings.
 - Short-circuit current rating of switchboards and over current protective devices.
 - UL listing and/or IEC Standard for series rating of installed devices.
 - Features, characteristics, ratings, and factory settings of individual over current protective devices and auxiliary components.
2. Wiring Diagrams: Power, signal and control wiring.
3. Full selectivity characteristic curves of upstream / down stream breakers.

Field quality – control test reports including the following:

- Test procedures used.
- Test results that comply with requirements.
- Results of failed tests and corrective action taken to achieve test results that comply with requirements.

Operation and Maintenance Data: for panel boards and components to include in emergency, operation, and maintenance manuals.

- Manufacturer's written instructions for testing and adjusting over current protective devices.
- Time-current curves, including selectable ranges for each type of over current protective device.

Testing Agency Qualifications: An independent agency, with the experience and capability to conduct the testing indicated.

Source Limitations: Obtain panel boards, over current protective devices, components and accessories through one source from a single manufacturer.

Product Options: Drawings indicate size, profiles, and dimensional requirements of panel boards and are based on the specific system indicated. Refer to Section “Product Requirements”.

Electrical Components, Devices and Accessories: Listed and labeled as defined in NFPA 70, Article 100, or as per relevant IEC specifications by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

H.18.1.4 Project Conditions

Environmental limitations: Rate equipment for continuous operation under the following conditions, unless otherwise indicated:

- Ambient Temperature: 50 deg C.
- Altitude: Sea Level

Thermal study and heat dissipation study with calculations of all components with guarantee that all necessary ventilation means are provided to ensure that breakers and all components are rated and operating as per design selected rating.

H.18.1.5 Coordination

Coordinate layout and installation of panel board and components with other construction that penetrates walls or is supported by them, including electrical and other types of equipment, raceways, piping and encumbrances to workspace clearance requirements.

Coordinate size and location of concrete bases. Cast anchor-bolt inserts into bases.

H.18.1.6 Extra Materials

Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

- Keys: six spares for each type of panel board cabinet lock.

H.18.2 Products

H.18.2.1 Manufacturers

Available Manufacturers: the manufacturers shall have a minimum of fifteen (15) years of experience in manufacturing the specified products and materials stated in these Specifications.

H.18.2.2 Manufactured Units

Enclosures: Flush or Surface mounted cabinets.

1. Rated for environmental conditions at installed location.
 - a. Outdoor Locations: IP55.
 - b. Other Wet or Damp Indoor Locations: IP44.
 - c. Indoor areas: IP40.

H.18.2.3 Distribution And Power Panelboards

GENERAL

Power and Distribution panelboards shall be equipped with thermal magnetic molded case circuit breakers.

Panelboards shall have 400 volt duty rating and shall have short circuit current interrupting capacity equal to or greater than the integrated equipment rating .

Short circuit tests on the overcurrent devices and on the panelboard structure shall be made simultaneously.

Panelboards shall conform to B.S. 5486 Part 2 and IEC 439-1, form 2b.

Panelboards circuit numbering shall be such that, starting at the top, odd numbers shall be used in sequence down the left-hand side and even numbers shall be used in sequence down the right-hand side.

Panelboards of main breaker rating 250 A and below shall have a maximum width of 60 cm.

Over voltage protection at feeder entry point shall be coordinated with protection provided upstream in main switchboard feeding distribution panelboard.

Instruments (3 ammeters, one voltmeter, one volt meter selector switch) shall be fully digital 3 pilot lights shall be installed in power and distribution panelboards (DP and PP).

CABINETS AND FRONTS

Panelboard assembly shall be enclosed in a electrozincated sheet steel cabinet. Cabinet shall be of sufficient size to provide a minimum gutter space of 10 cm on all sides. The thickness of the sheet steel shall be minimum 2 mm.

All covers will be equipped with handle.

Fronts shall include doors and have flush, brushed stainless steel cylinder tumbler - type locks with catches and spring loaded door pulls. The flush lock shall not protrude beyond the front of the adjustable indicating trim clamps which shall be completely concealed when the doors are closed. Fronts shall have approved directories with name of panel, number of phases, wires and voltage written on them. Doors shall be mounted by completely concealed steel hinges. Fronts shall not be removable with door in the locked position. A circuit directory card shall provide a space of at least 0.5cm high x 7cm long or equivalent for each circuit.

In addition to covers, detachable panels, of Plexiglas shall be provided to avoid accidental contact with the busbars on the opening of the door and the removing of the metal cover.

The directory shall be typed to identify the load fed by each circuit. Each incoming and outgoing will have an engraved label that will be placed on covers inside the enclosure.

Fronts shall be of code gauge, full finished steel with rust-inhibiting primer and baked enamel finish. Color shall be gray to RAL 7032.

Joints shall be welded, galvanized and reinforced where necessary and galvanized after fabrication.

PANELBOARD BUS ASSEMBLY

Bus for connections to the branch circuit breakers shall be the "Distributed Phase" or "Phase Sequence" Type.

Connection between busbars and breakers shall be made with rigid busbars only.

Three-phase, four-wire bussing shall be such that any three adjacent single-pole breakers are individually connected to each of the three different phases in such a manner that two or three pole breakers can be installed at any location. All current carrying parts of the bus assembly shall be plated.

Main and neutral buses shall be minimum 98% conductivity rectangular copper bars, provided with bolted-type lugs as necessary.

Buses shall be rigidly supported and insulated and be so designed that branch circuits can be removed without disturbing adjacent units or changed without additional machining, drilling or tapping.

All screws and bolts used for making copper connections shall be equipped with lock washers. Reverted connections will not be acceptable.

Mains shall be equipped with solderless pressure indent type connectors and have means to prevent swiveling of connector.

Neutral busbars shall be full size and shall incorporate one neutral terminal for each single pole and neutral way.

Aluminum shall not be used for any interior panelboard parts.

Back pan or mounting on which buses and branches are mounted shall be rigid to properly support the component parts.

Reinforcing of back pan shall be by flanging or addition of angle iron.

EARTHING

An acceptable terminal bar for equipment earthing conductors shall be provided with minimum number of cable terminations equal to the single pole number of ways of the panelboard.

Cabinets shall be provided with an earth connector welded to it.

MOLDED CIRCUIT BREAKERS

Molded case circuit breakers shall be as specified under "CIRCUIT BREAKERS" have trip settings, and number of poles, as applicable. All circuit breakers shall have their ampere trip rating clearly marked and visible. Rated insulation voltage shall be 750V. Rated impulse withstand voltage shall be 8 KV.

The main circuit breaker shall be Molded Case type Fixed, Manually or motor operated, 3 poles with the following features:

ICS = 40 kA.

1 auxiliary contacts – ON/OFF signaling status.

1 Alarm auxiliary contacts

The branch circuit breakers shall be Molded Case type Fixed, Manually or motor operated, 3 pole with ICU = 35kA.

The main incoming shall be Molded Case type Fixed & manually operated, 3 poles with rotary handle interlocked with the door. It will include the following features:

ICS = 40kA.

1 auxiliary contacts - ON/OFF signaling status

1 Alarm auxiliary contacts

PANELBOARD INSTALLATION

Panelboard shall be aligned, leveled and securely fastened to the building.

Connecting conduits shall not be used to support the panelboard.

All unused openings in panelboard cabinets shall be properly closed.

Panelboard interiors shall not be installed in cabinets until all conduit connections to the cabinet have been completed.

Trim shall be installed plumb and square to finish painting.

Trim for flush mounted cabinets shall be installed in plaster frame, flush with finished wall.

Concealed surfaces of cabinets shall be given on site a heavy application of emulsified asphalt prior to installation.

Free standing panelboards when installed in electrical close, or rooms with depressed floors shall be provided with galvanized steel support structures to raise the level of the panel to 10 cm above the original floor level.

EARTHING

An acceptable terminal bar for equipment earthing conductors shall be provided with a minimum number of cable terminations equal to the single pole number of ways of the panelboard.

Cabinet shall be provided with a earth connector welded to it.

PANEL BOARD SHORT-CIRCUIT RATING

Fully rated to interrupt symmetrical short-circuits current available at terminals, based on short circuit calculations findings to be submitted by contractor. If required short circuit interrupting capacity is larger than calculated one, on vice versa, the larger figure shall be used.

H.18.2.4 Lighting Panelboard

GENERAL

Lighting panelboards shall be equipped with main MCB with residual current device (300mA) and branch thermal magnetic miniature type circuit and residual current device 30mA for socket outlets circuit.

Panelboards shall have 400 volt duty rating.

Panelboards circuit numbering shall be such that, starting at the top, odd numbers shall be used in sequence down the left-hand side and even numbers shall be used in sequence down the right-hand side.

RESIDUAL CURRENT DEVICE

Residual current device (RCD) shall be current operated type with non adjustable low level earth faults sensitivity of 300 mA, 100mA or 30mA as indicated.

It shall fit in standard lighting panelboards.

A push-to-test mechanism shall be provided to ensure proper operation.

Enclosure shall be glass reinforced.

RCD shall have 9000A interrupting capacity or shall be protected upstream with a 9000 A Breaking capacity device.

RCD shall comply with BS 4293:1983 or IEE 27.

EARTHING

An acceptable terminal bar for equipment earthing conductors shall be provided with minimum number of cable terminations equal to the single pole number of ways of the panelboard.

Cabinets shall be provided with an earth connector welded to it.

CABINETS AND FRONTS

Panelboard assembly shall be enclosed in a electrozincated cabinet. Panelboards shall conform to B.S. 5486 Part 13 1979 and IEC 439.

Cabinets shall be of sufficient size to provide a minimum gutter space of 10cm on all sides. The thickness of the sheet steel shall be minimum 1.5 mm.

Fronts shall include doors and have flush, brushed stainless steel cylinder tumbler-type locks with catches and spring loaded door pulls. The flush lock shall not protrude beyond the front of the adjustable indicating trim clamps which shall be completely concealed when the doors are closed. Fronts shall have approved directories with name of panel, number of phases, wires and voltage written on them.

Doors shall be mounted by completely concealed steel hinges. Fronts shall not be removable with door in the locked position. A circuit directory card shall provide a space of at least 0.5 cm high x 7 cm long or equivalent for each circuit.

The directory shall be typed to identify the load fed by each circuit.

Fronts shall be of code gauge, full finished steel with rustinhibiting primer and baked enamel finish. Color shall be RAL 7032.

Joints shall be welded, galvanized and reinforced where necessary and galvanized after fabrication.

PANELBOARD BUS ASSEMBLY

Bus for connections to the branch circuit breakers shall be the "Distributed Phase" or "Phase Sequence" Type.

Three-phase, four-wire bussing shall be such that any three adjacent single-pole breakers are individually connected to each of the three different phases in such a manner that two or three pole breakers can be installed at any location. All current carrying parts of the bus assembly shall be plated.

Main and neutral buses shall be minimum 98% conductivity rectangular copper bars, provided with bolted-type lugs as necessary.

Buses of lighting panelboards shall be suitably braced for a minimum short circuit duty equal to 9000 A unless otherwise indicated.

Bus shall be rigidly supported and insulated and be so designed that branch circuits can be removed without disturbing adjacent units or changed without additional machining, drilling or tapping.

All screws and bolts used for making copper connections shall be equipped with lock washers. Riveted connections will not be acceptable.

Mains shall be equipped with solderless pressure indent type connectors and have means to prevent swiveling of connector.

Neutral busbars shall be full size and shall incorporate one neutral terminal for each single pole and neutral way.

Back pan or mounting on which buses and branches are mounted shall be rigid to properly support the component parts.

Reinforcing of back pan shall be by flanging or addition of angle iron.

Buses, connectors, and terminals shall be silver plated to a minimum thickness of 0.1 mm.

H.18.2.5 Motor Starter Panel

GENERAL

The motor starter panel (indicated MSP) shall include bus assembly, cabinet and front, molded case circuit breakers, motor starters, and all necessary parts to install complete unit.

Motor starter panel shall be as in accordance with international standards IEC 439, EN 60439, SB section 13, VDE, BS. Tested and approved by acknowledged test laboratories.

Maximum main breaker, or incomer size shall not exceed 250 Amperes.

CABINET

Motor starter panel shall be similar to IEC Form 2b.

Motor starter panel assembly shall be enclosed in cabinet of high quality steel which gives cathodic protection and long durability. Surface treated doors and covers shall be produced of phosphated high-quality steel-plates.

The finish painting consists of epoxy powder with a high coloring-body density, laid on with an electrostatic process which combines durability and high quality.

Cabinet interior structure and branch devices shall be so designed that the completely assembled MSP can be related before wiring. Cabinets shall be wall mounted, and with separation barrier as per form 2 according to IEC 439-1 (1992).

Cabinets shall be equipped with a three-piece front with doors one for the main breaker and one for starters.

BUSSING ASSEMBLY

Line side bussing from the main incoming feeder terminals to all branch circuit breakers and circuit breaker disconnects shall be made without the use of cable.

Busbars shall be made of copper.

Busbars shall be placed in an independent compartment located at the rear of the board.

Busbars shall be vertical arrangement, it shall be used for currents up to 225A. Connections shall be carried out with plugs which can sustain maximum 32 Amp.

Busbars short circuit capacity shall be 16 KA RMS.

Insulation materials shall have self-extinguishing index UL94-40.

MOTOR STARTERS, CIRCUIT BREAKER DISCONNECTS AND BRANCH CIRCUIT BREAKERS

Circuit breakers shall be MCCB bolt-on type for motors equal to and larger than 15 hp. and shall be equipped with individually insulated, braced and protected line side connectors. All multiple pole breakers shall be common trip.

Provisions for future breakers shall be such that no additional electrical connectors or other mounting hardware will be required to add breakers.

Breakers shall be as specified under circuit breakers.

Circuit breakers shall be miniature MCB type for motors rated below 15 hp.

Unit doors covering circuit breakers and motor starters shall be dual interlocked to prevent unauthorized opening with disconnect handle in the ON position, and to prevent unauthorized moving of the disconnect handle to the ON position with unit door open. Disconnect handles shall be trip indicating by assuming a position midway between ON and OFF. Disconnect handles shall have provisions for a minimum of three padlocks in the OFF position.

Each unit door shall include a starter reset mechanism and additional control devices located inside panel and as specified on the plans.

Motor starters shall be across-the-line magnetic type rated in accordance with NEMA/IEC Standards, sizes and horsepower ratings for motors 15 hp and smaller. Starter contacts shall be double-break silver alloy type and shall be replaceable removing the starter from its mounting. Starter coils shall be replaceable from the front without removing the starter from its mounting. Overload relays shall be melting alloy type. Thermal units shall be one-piece construction and interchangeable. Thermal units must be in place to operate starter.

Motor starters shall be star-delta, soft starter type or auto transformer type for motors larger than 15 hp.

SERVICE CONDITIONS FOR STARTERS

Utilization category AC-3 according to IEC 947-4-1.

FEATURES

The following features must be added in the Motor Starter Panel:

- 1 Hand-off-Auto selector switch per fan.
- Control transformer including single secondary fuse within same starter enclosure.
- Control circuit fuse (type Legrand).
- Auxiliary contacts and relays for remote control and interface with BMS.

LABELING

Components of each module shall have individual printed label identifying size, voltage, ampere rating, etc. Starter wiring diagram and overload thermal cutout device installation instruction shall be attached to each starter door.

INTERCABLING

It shall be completely done in factory for all cabling within the Panel.

TERMINAL BLOCKS

Terminal blocks shall be installed and internally connected by the manufacturer, for all internal and external wire number. Each terminal point shall have a large marking area or to be equipped with two marking areas.

In addition, with each group of terminals per unit, a minimum of 20% unconnected extra non-load terminals, but not less than one, shall be provided for the Contractor's external connections.

OPERATING HANDLE

It shall be interlocked with cover to prevent opening of cover while handle is in the "ON" position. The handle must be moved to "OPEN COVER" position for door opening.

This operation needs a door, with cover we cannot make it.

H.18.2.6 Pump Control Panel

GENERAL

The Contractor shall supply and install the pump control panel (indicated PCP, EPCP). They shall include bus assembly, cabinet and front, molded case circuit breakers, motor starters, and all necessary parts to install complete unit.

Arrangement shall be similar to IEC 439-1 form 2b (1992).

CIRCUIT BREAKERS

Circuit breakers shall be molded case bolt-on for motors equal and larger than 15 hp and miniature type for motors smaller than 15 hp shall be as specified for under "CIRCUIT BREAKERS".

STARTERS

Starters shall incorporate contactors made of a glass polyester case with silver cadmium oxide alloy contacts, molded coils, stainless steel kickout springs, U-type magnet and a shock absorber baseplate. Overload relays shall be three-pole, inverse and ambient compensated type.

CONTROL AND MISCELLANEOUS DEVICES

Control relays shall be the heavy duty, industrial or machine tool type with at least two normally closed and two normally open spare contacts. Relays shall be rated NEMA designation A600 or N600, as required.

Control Power Transformer shall be provided as applicable to limit the control voltage to 230 volts, and to eliminate the need for phase-to neutral voltage. It shall be 2- winding, dry type and of suitable VA rating but not less than 75 volt-amperes.

Automatic Alternator, if any, shall control the operation of two separately enclosed motor starters so that they operate alternately at successive closing of a single pressure or float switch (to equalize equipment wear). The second float or pressure switch is set to start the idle pump in case one pump will not handle the load. Both pumps then working to handle the demand.

Pushbuttons shall be heavy duty, oil tight type with removable contact blocks. Contact ratings shall be 10- ampere continuous current. Pushbuttons shall be provided with chrome-plated metal or anodized aluminum mounting rings.

Selector switches shall be heavy-duty oil tight type with removable contact blocks and bat type lever operators. Contact ratings shall be 10 ampere, continuous current. Selectors shall be provided with chrome-plated metal or anodized aluminum mounting rings.

Indicating lights shall be heavy-duty, oil tight type with glass lenses. Lights shall be equipped with reduced voltage transformers and 6-volt lamps. Indicating lights shall be provided with chrome-plated metal or anodized aluminum mounting rings.

Extra secondary contacts for one or more remote controls terminal wiring blocks, etc. shall be provided as required.

All devices shall be suitable for operating at 230 volts, 50 Hz when connected between phase and neutral.

LABELING

Components of each module shall have individual printed label identifying size, voltage, ampere rating, etc. Starter wiring diagram and overload thermal cutout device installation instruction shall be attached to each starter door.

INTERCABLING

It shall be completely done in factory for all cabling within the Panel.

TERMINAL BLOCKS

Terminal blocks shall be installed and internally connected by the manufacturer, for all internal and external wire number. Each terminal point shall have a large marking area or to be equipped with two marking areas.

In addition, with each group of terminals per unit, a minimum of 20% unconnected extra non-load terminals, but not less than one, shall be provided for the Contractor's external connections.

OPERATING HANDLE

It shall be interlocked with cover to prevent opening of cover while handle is in the "ON" position. The handle must be moved to "OPEN COVER" position for door opening.

H.18.3 Execution

H.18.3.1 Installation

Install panel boards and accessories according to IEC 60364 and NEMA PB1.1.

Mount top of trim 74 inches (J880 mm) above finished floor, unless otherwise indicated.

Mount plumb and rigid without distortion of box. Mount recessed panel boards with fronts uniformly flush with wall finish.

Install over current protective devices and controllers.

- Set field-adjustable switches and circuit-breaker trip ranges.

Install filler plates in unused spaces.

Stub four 1-inch (27-GRC) empty conduits from panel board into accessible ceiling space or space designated to be ceiling space in the future. Stub four 1-inch (27-GRC) empty conduits into raised floor space or below slab not on grade.

Arrange conductors in gutters into groups and bundle and wrap with wire ties after completing load balancing.

H.18.3.2 Identification

Identify field-installed conductors, interconnecting wiring, and components; provide warning signs as specified in Section "Electrical Identification."

Create a directory to indicate installed circuit loads after balancing panel board loads. Obtain approval before installing. Use a computer or typewriter to create directory; handwritten directories are not acceptable.

Panel board Nameplates: Label each panel board with engraved metal or laminated-plastic nameplate mounted with corrosion-resistant screws.

H.18.3.3 Connections

Ground equipment according to Section "Earthing and Bonding."

Connect wiring according to Section "Conductors and Cables."

H.18.3.4 Field Quality Control

Prepare for acceptance tests as follows:

- Test insulation resistance for each panel board bus, component, connecting supply, feeder and control circuit
- Test continuity of each circuit

Testing Agency: Owner will engage a qualified testing and inspecting agency to perform field tests and inspections and prepare test reports.

Testing Agency: Engage a qualified testing and inspecting agency to perform the following field tests and inspections and prepare test reports:

Perform the following field tests and inspections and prepare test reports.

- Perform each electrical test and visual and mechanical inspection stated in IEC switches and for molded-case circuit breakers. Certify compliance with test parameters,

- Correct malfunctioning units on-site, where possible, and retest to demonstrate compliance; otherwise, replace with new units and retest.

Load Balancing: After Substantial Completion~ but not more than 60 days after Final Acceptance, measure load balancing and make circuit changes.

- Measure as directed during period of normal system loading.
- Perform load-balancing circuit changes outside normal occupancy/working schedule of the facility and at time directed. Avoid disrupting critical 24-hour services such as fax machines and on-line data processing, computing, transmitting, and receiving equipment.
- After circuit changes, recheck loads during normal load period. Record all load readings before and after changes and submit test records.
- Tolerance: Difference exceeding 20 percent between phase loads, within a panel board, is not acceptable. Rebalance and recheck as necessary to meet this minimum requirement.

Infrared Scanning: After Substantial Completion, but not more than 60 days after Final Acceptance, perform an infrared scanning of each panel board. Remove panel fronts so joints and connections are accessible to portable scanner.

- Follow-up Infrared Scanning: Perform an additional follow-up infrared scan of each panel board 11 months after date of Substantial Completion.
- Instrument: Use an infrared scanning device designed to measure temperature or to detect, significant deviations from normal values. Provide calibration record for device.
- Record of Infrared Scanning: Prepare a certified report that identifies panel boards checked and describes scanning results. Include notation of deficiencies detected, remedial action taken, and observations after remedial action.

H.18.3.5 Cleaning

On completion of installation inspect interior and exterior of panel boards. Remove paint splatters and other spots. Vacuum dirt and debris; do not use compressed air to assist in cleaning. Repair exposed surfaces to match original finish.

H.19. LOW VOLTAGE MOTOR CONTROL CENTERS

H.19.1 General

H.19.1.1 Related Documents

Drawings and general provisions of the Contract, including General and Supplementary Conditions and Specification Sections, apply to this Section

H.19.1.2 Summary

This Section includes motor-control centers for use on AC circuits rated 600 V and less.

H.19.1.3 Submittals

Product Data: For each type of controller and each type of motor-control center. Include dimensions and manufacturer's technical data on features, performance, electrical characteristics, ratings, and finishes.

Shop Drawings: For each motor-control center.

- Include dimensioned plans, elevations, sections, and details, including required clearances and service space around equipment. Show tabulations of installed devices, equipment features, and ratings. Include the following:
 - a. Each installed unit's type and details.
 - b. Nameplate legends.
 - c. Short-circuit current ratings of buses and installed units.
 - d. Vertical and horizontal bus capacities.
 - e. UL listing for series tarring of over current protective devices in combination controllers.
 - f. Features, characteristics, ratings, and factory settings of each motor-control center unit.
- Wiring Diagrams: Power, signal, and control wiring for class and type of motor-control center. Provide schematic wiring diagram for each type of controller.

Coordination Drawings: Floor plans, drawn to scale, showing dimensioned layout, required working clearances, and required area above and around motor-control centers where pipe and ducts are prohibited. Show motor-control center layout and relationships between electrical components and adjacent structural and mechanical elements. Show support locations, type of support, and weight on each support. Indicate field measurements.

Qualification Data: for manufacturer

Field quality-control test reports.

Operation and Maintenance Data: For motor-control centers, all installed devices, and components to include in emergency, operation, and maintenance manuals. In addition to items specified in Section "Operation and Maintenance Manuals", include the following:

- Routine maintenance requirements for motor-control centers and all installed components.
- Manufacturer's written instructions for testing and adjusting over current protective devices.

Load-Current and Overload-Relay Heater List: Compile after motors have been installed and arrange to demonstrate that selection of heaters suits actual motor nameplate full-load currents.

Load-Current and List of Settings of Adjustable Overload Relays: Compile after motors have been installed and arrange to demonstrate that dip switch settings for motor running overload protection suit actual motor to be protected.

H.19.1.4 Quality Assurance

Manufacturer Qualifications: A qualified manufacturer. Maintain, within 30Km of Project site, a service center capable of providing training, parts, and emergency maintenance and repairs.

Testing Agency Qualifications: An independent agency, with the experience and capability to conduct the testing indicated, that is a member company of the International Electrical Testing Association (Kema, TUV, Veritas etc..), and that is acceptable to authorities having jurisdiction.

- Testing Agency's Field Supervisor: Person currently certified by the International Electrical Testing Association, or one of the National Engineering Control Audit Institute for Certification in Safety Engineering Technologies to supervise on-site testing specified in Part 3.

Source Limitations: Obtain motor-control centers and controllers of a single type through one source from a single manufacturer.

Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

Comply with NFPA 70.

Product Selection for Restricted Space: Drawings indicate maximum dimensions for motor-control centers, including clearances between motor-control centers, and for adjacent surfaces and other items. Comply with indicated maximum dimensions and clearances .

H.19.1.5 Delivery, Storage, and Handling

Deliver motor-control centers in shipping splits of lengths that can be moved past obstructions in delivery-path as indicated.

Handle motor-control centers according to the following:

- NEMA ICS 2.3, "Instructions for the Handling, Installation, Operation, and Maintenance of Motor Control Centers Rated Not More Than 600 Volts."
- NECA 402, "Recommended Practice for Installing and Maintaining Motor Control Centers."

H.19.1.6 Project Conditions

Interruption of Existing Electrical Service: Do not interrupt electrical service to facilities occupied by Owner or others unless permitted under the following conditions and then only after arranging to provide temporary electrical service according to requirements indicated:

- Notify Owner no fewer than three days in advance of proposed interruption of electrical service.
- Indicate method of providing temporary electrical service.
- Do not proceed with interruption of electrical service without Owner's written permission.

H.19.1.7 Coordination

Coordinate layout and installation of motor-control centers with other construction including conduit, piping, equipment, and adjacent surfaces. Maintain required workspace clearances and required clearances for equipment access doors and panels.

Coordinate size and location of concrete bases. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified in Section "Cast-in-Place" Concrete."

Coordinate installation of roof curbs, equipment supports, and roof penetrations.

Coordinate features of motor-control centers, installed units, and accessory devices with pilot devices and control circuits to which they connect.

Coordinate features, accessories, and functions of each motor-control center, each controller, and each installed unit with ratings and characteristics of supply circuit, motor, required control sequence, and duty cycle of motor and load.

H.19.1.8 Extra Materials

Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

- Spare Fuses: Furnish one spare for every five installed, but no fewer than one set of three of each type and rating.
- Indicating Lights: Two of each type installed.

H.19.2 Products

H.19.2.1 Manufacturers

Manufacturers : Subject to compliance with requirements, provide products by one of the following:

H.19.2.2 Motor-Control Centers

Wiring: NEMA ICS 3.

Enclosures: Surface-mounting cabinets as indicated IP54 or NEMA approved equivalent, unless otherwise indicated to comply with environmental conditions at installed location.

- Outdoor Locations: IP or NEMA approved equivalent.
- Compartments: Modular; individual doors with concealed hinges and quick-captive screw fasteners. Interlocks on combination controller units requiring disconnecting means in off position before door can be opened or closed, except by operating a permissive release device. Arrangement similar to IEC 439 form 3b.
- Interchangeability: Compartments constructed to allow for removal of units without opening adjacent doors, disconnecting adjacent compartments, or disturbing operation of other units in motor-control center; same size compartments to permit interchangeability and ready rearrangement of units, such as replacing three single units with a unit requiring three spaces, without cutting or welding.
- Wiring Spaces: Wiring channel in each vertical section for vertical and horizontal wiring to each unit compartment; supports to hold wiring in place.

Short-Circuit Current Rating for Each Section: Equal to or greater than indicated available fault current in symmetrical amperes at motor-control center location.

H.19.2.3 Buses

Material: Plated hard-drawn copper, 98 percent conductivity.

Ampacity Ratings: As indicated for horizontal and vertical main buses.

Neutral Buses: Full size unless otherwise indicated.

Equipment Ground Bus: Non insulated, horizontal configuration; adequate for equipment ground conductors; bonded to enclosure.

Horizontal Bus Arrangement: Main phase, neutral and ground buses extended with same capacity the entire length of motor-control center, with provision for future extension at both ends by bolt holes and captive bus splice sections or equivalent.

Short-Circuit Withstand Rating: Same as short-circuit current rating of section.

H.19.2.4 Functional Features

Description: Modular arrangement of controllers, control devices, over current protective devices, transformers, panel boards, instruments indicating panels, blank panels, and other items mounted in compartments of motor-control center.

Controller Units: Combination controller units of types and with features, ratings, and circuit assignments indicated.

- Install units up to and including NEMA Size 3 on draw out mountings with connectors that automatically line up and connect with vertical-section buses while being racked into their normal, energized position.
- Provide units with short-circuit current ratings equal to or greater than short-circuit current rating of motor-control center section.

- Equip units in Type B and Type C motor-control centers with pull-apart terminal strips or draw out terminal boards for external control connections.
- Controller Disconnecting Means: Factory-assembled combination disconnect and controller.

a. Fusible Disconnecting Means: NEMA KS 1, heavy-duty, fusible switch with rejection-type fuse clips rated for fuses. Select and size fuses to provide Type 2 protection according to IEC 60947-4-1, as certified by an NRTL.

b. No fusible Disconnecting Means: NEMA KS 1, heavy-duty, no fusible switch.

c. Circuit-Breaker Disconnecting Means: NEMAAB 1, motor-circuit protector with field-adjustable, short-circuit trip coordinated with motor locked-rotor amperes.

Over current Protective Devices: Individual feeder-tap units through 225-A rating shall draw out mountings with connectors that automatically line up and connect with vertical-section buses while being racked into their normal, energized positions.

Transient Voltage Surge Suppressors: Connect to motor-control center bus.

Spaces and Blank Units: Compartments fully bused and equipped with guide rails or equivalent, ready for insertion of draw out units.

Spare Units: Type, sizes, and ratings indicated; installed in compartments indicated "spare."

H.19.2.5 Accessories

Devices shall be factory installed in controller enclosure, unless otherwise indicated.

Push-Button Stations, Pilot Lights, and Selector Switches: NEMA ICS 2, heavy-duty type.

Stop and Lockout Push-Button Station: Momentary-break, push-button station with a factory-applied hasp arranged so padlock can be used to lock push button in depressed position with control circuit open.

Control Relays: Auxiliary and adjustable time-delay relays.

Elapsed Time Meters: Heavy duty with digital readout in hours.

Meters: Panel type. 2-1/2-inch (64-mm) minimum size with 90- or 120-degree scale and plus or minus 2 percent accuracy. Where indicated, provide transfer device with an off position. Meters shall indicate the following:

- Ammeter: Output current with current sensors rated to suit application.
- Voltmeter: Output voltage.
- Frequency Meter: Output frequency.

Multifunction Digital-Metering Monitor: UL-listed or -recognized, microprocessor-based unit suitable for three- or four-wire systems and with the following features:

- Inputs from sensors or 5-A current-transformer secondaries, and potential terminals rated to 600 V.
- Switch-selectable digital display of the following: a. Phase Currents, Each Phase: Plus or minus 1 percent b. Phase-to-Phase Voltages, Three Phase: Plus or minus 1 percent. c. Phase-to-Neutral Voltages, Three Phase: Plus or minus 1 percent. d. Three-Phase Real Power: Plus or minus 2 percent e. Three-Phase Reactive Power: Plus or minus 2 percent f. Power Factor: Plus or minus 2 percent. g. Frequency: Plus or minus 0.5 percent. h. Integrated Demand with Demand Interval Selectable from 5 to 60 Minutes: Plus or minus 2 percent i. Accumulated energy, in megawatt hours (joules), plus or minus 2 percent; stored values unaffected by power outages for up to 72 hours.
- Mounting: Display and control unit flush or semiflush mounted in instrument compartment door.

Phase-Failure and Under voltage Relays for Bypass Controllers: Solid-state sensing circuit with isolated output contacts for hard-wired connection. Provide adjustable under voltage setting.

Current-Sensing, Phase-Failure Relays: Solid-state sensing circuit with isolated output contacts for hardwired connection; arranged to operate on phase failure, phase reversal, current unbalance of from 30 to 40 percent or loss of supply voltage; with adjustable response delay.

Spare-Fuse Cabinet: Identified cabinet with hinged lockable door.

H.19.2.6 Factory Finishes

Finish: Manufacturer's standard grey paint applied to factory-assembled and -tested, motor-control centers before shipping.

H.19.3 Execution

H.19.3.1 Examination

Examine areas and surfaces to receive motor-control centers for compliance with requirements, installation tolerances, and other conditions affecting performance.

- Proceed with installation only after unsatisfactory conditions have been corrected.

H.19.3.2 Applications

Select features of each controller to coordinate with ratings and characteristics of supply circuit and motor; required control sequence; duty cycle of motor, controller, and load; and configuration of pilot device and control circuit affecting controller functions.

Select horsepower rating of controllers to suit motor controlled.

H.19.3.3 Installation

Anchor each motor-control center assembly to steel-channel sills arranged and sized according to manufacturer's written instructions. Attach by bolting. Level and grout sills flush with motor-control center mounting surface.

Install motor-control centers on concrete bases.

Comply with mounting and anchoring requirements specified in Section "Electrical Supports and Seismic Restraints."

H.19.3.4 Concrete Bases

Coordinate size and location of concrete bases. Verify structural requirements with structural engineer.

Concrete materials and installation requirements are specified.

H.19.3.5 Identification

Identify motor-control center, motor-control center components, and control wiring according to Section "Electrical Identification."

Operating Instructions: Frame printed operating instructions for motor-control centers, including control sequences and emergency procedures. Fabricate frame of finished metal, and cover instructions with clear acrylic plastic. Mount on front of motor-control centers.

H.19.3.6 Control Wiring Installation

Install wiring between motor-control devices according to Section "Conductors and Cables."

Bundle, train, and support wiring in enclosures.

Connect hand-off-automatic switch and other automatic-control devices where applicable.

- Connect selector switches to bypass only manual- and automatic-control devices that have no safety functions when switch is in hand position.
- Connect selector switches with motor-control circuit in both hand and automatic positions for safety-type control devices such as low- and high-pressure cutouts; high temperature cutouts, and motor overload protectors.

H.19.3.7 Connections

Conduit installation requirements are specified in other sections. Drawings indicate general arrangement of conduit, fittings, and specialties.

Ground equipment according to these Specifications Documents.

H.19.3.8 Field Quality Control

Prepare for acceptance tests as follows:

- Test insulation resistance for each motor-control center element, bus, and component, connecting supply, feeder, and control circuit.
- Test continuity of each circuit

Manufacturer's Field Service: Engage a factory-authorized service representative to perform the following:

- Inspect controllers, wiring, components, connections, and equipment installation. Test and adjust controllers, components, and equipment.
- To assist in field testing of equipment including pretesting and adjusting of solid-state controllers.
- Report results in writing.

Testing Agency: Owner will have the right to engage a qualified testing and inspecting agency to perform field tests and inspections and prepare test reports.

Perform the following field tests and inspections and prepare test reports:

- Perform each electrical test and visual and mechanical inspections, except for optional tests, stated in NET A ATS "Motor Control Centers." Certify compliance with test parameters.
- Correct malfunctioning units on-site, where possible, and retest to demonstrate compliance; otherwise, replace with new units and retest.

H.19.3.9 Adjusting

Set field-adjustable switches and circuit-breaker trip ranges.

H.19.3.10 Demonstration

Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain components of motor-control centers! Including solid-state controllers. Refer to Section "Training."

H.20. MOTOR STARTERS

H.20.1 General

H.20.1.1 Description

All motor starters and motor control stations including installation and connection (whether furnished with the equipment specified in other Sections or otherwise) shall meet these specifications.

H.20.1.2 Related Work

Other sections which specify motor driven equipment, except elevator motor controllers.

General electrical requirements and items that is common to more than one Section GENERAL PROVISIONS FOR ELECTRICAL WORK.

Requirements for personnel safety and to provide a low impedance path for possible ground fault currents: Section EARTHING.

For multiple motor control assemblies, which include motor starters: Section MOTOR STARTERS.

H.20.1.3 Submittals

Submit in accordance with Section, BASIC ELECTRICAL MATERIALS AND METHODS:

- Shop Drawings:

1. Sufficient information, clearly presented, shall be included to determine compliance with drawings and specifications.
2. Current protection, branch circuit, over current protection, wiring diagrams, starting characteristics, interlocking and accessories.

- Manuals:

1. Submit, simultaneously with the shop drawings, companion copies of complete maintenance and operating manuals, including technical data sheets, wiring diagrams and information for ordering replacement parts.
 - a. Wiring diagrams shall have their terminals identified to facilitate installation, maintenance and operation.
 - b. Wiring diagrams shall indicate internal wiring for each item of equipment and interconnections between the items of equipment.
 - c. Elementary schematic diagrams shall be provided for clarity of operation.
 2. Two weeks prior to the project final inspection, submit four copies of the final updated maintenance and operating manual to the Resident Engineer. (Update manual to include any information necessitated by shop drawing approval).
- Certification: Two weeks prior to final inspection, unless otherwise noted, submit four copies of the following certifications to the Resident Engineer:
 1. Certification by the manufacturer that the controllers have passed the factory 24 hour operational tests. (This certification must be furnished to the Resident Engineer prior to shipping the controller to the job site.)
 2. Certification by the manufacturer that high voltage motor controller(s) conforms to the requirements of the drawings and specifications. (This certification must be furnished to the Resident Engineer prior to shipping the controller to the job site.)

Certification that the equipment has been properly installed, adjusted, and tested.

H.20.1.4 Applicable Publications

Publications listed below (including amendments, addenda, revisions, supplements and errata) form a part of this specification to the extent referenced. Publications are referenced in the text by basic designation only.

Institute of Electrical and Electronic Engineers (IEEE): 519-92 Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems

C37 Standard Surge Withstand Capability (SWC) Tests for Protective Relays and Relay Systems

National Electrical Manufacturers Association (NEMA):

ICS 1-93 Industrial Control and Systems General Requirements

ICS 1.1-84 Safety Guidelines for the Application, Installation and Maintenance of Solid State Control

ICS 2-93 Industrial Control and Systems, Controllers, Contactors and Overload Relays Rated Not More Than 2000 Volts AC or 750 Volts DC

ICS 6-93 Industrial Control and Systems Enclosures

ICS 7-93 Industrial Control and Systems Adjustable-Speed Drives

ICS 7.1-95 Safety Standards for Construction and Guide for Selection, Installation and Operation of Adjustable- Speed Drives

National Fire Protection Association (NFPA): 70-99 National Electrical Code (NEC)

Underwriters Laboratories Inc. (UL): 508-99 Industrial Control Equipment

H.20.2 Products

H.20.2.1 Motor Starter

Motor Starters shall be built and sized in accordance with NEMA Industrial Control Standards, ICS-1970 or IEC 947 or approved equal. Starters shall be non-reversing, magnetic type unless otherwise indicated or specified.

Starters shall be equipped with necessary control contact for connection to BMS as per the Contractor's approved shop drawings.

Contactors shall have their contact easily accessible for inspection and maintenance.

It shall not be possible to remove the arc-quenching chamber when the contactor is energized.

The arc-quenching chamber shall be fully enclosed in order to prevent the escape of hot gases.

It shall be impossible to operate the main and auxiliary contacts manually by means of the position indicator.

Auxiliary switches shall be equipped with fail-safe linkage in order to exclude false signals.

The rated withstand voltage shall be 600 V and the test voltage shall be 3000 V for 1 minutes (IEC60 947-1).

The insulation class coil shall be "B" according to VDE 0660.

All starters shall comply with coordination type 2 per IEC60 947-4-1 when installed in MCC, MSP, CP or PCP.

All starters shall be provided with thermal cutout devices in each phase calibrated for close protection of the motors against overloads. These devices shall trip the starters in case of overload and shall not allow it to be reset except

manually. The thermal overload relays shall be adjustable from 90 to 110% of nominal rating. A single calibration adjusts all three legs. The overload relay shall be ambient compensated.

All motors 15 HP and larger shall have their starters equipped with integrated multiple function solid state motor protection for:

- Thermal overload
- Asymmetry/ phase failure
- High overload/stalling

Motor starters larger than 15 hp. and motors for operation under fire shall also have earth fault protection integrated within the solid state motor protection unit.

The starter shall be provided with auxiliary contacts for the connection of signaling, interlocking and other circuits as required for the controls. (At least 2 No. + 2 C) and as required by Building management system.

Unless otherwise indicated, all starters shall be provided with START-STOP pushbuttons, and RED & GREEN pilot lights, all located on the starter front cover.

An overload reset button shall be provided inside the cover. Pushbuttons shall be momentary contact or maintained type as applicable to the function of control.

Starters shall have horsepower ratings at least equal to ratings of motors they serve.

Voltage of control circuit shall not exceed 220 volts.

Starters shall be electrically held in, providing inherent under voltage release.

Starters when not part of a motor control center and are located indoors shall be encased in a NEMA 1 gasketed dust-proof enclosure, unless otherwise indicated.

"Star-delta" starters if any shall have additional "Star" and "Delta" contactors which shall be electrically and mechanically interlocked to close the motor in "Delta" connection with the supply after the "Star" contactor has opened. A timing device shall be fitted to provide and adjust time in "Star" before changing over to the Delta connection.

"Star-Delta" Starters shall provide close transition.

Schematic wiring diagram of all starters shall be provided on the interior of starter front cover.

Auto-transformer type starter shall not be approved.

H.20.2.2 Motor Circuit Protective Device

Motor circuit protective devices shall comply with IEC standards 60957-1 and 60957-2. Alternative proposals to ratings shown on the Contractor's approved shop drawings based on manufacturers recommendations shall be subject to the Engineer's Approval. The Contractor shall in any case be responsible to assure that the circuit protective devices shall carry the starting current with no tripping, and if reducing trip rating results in a reduction in frame size, the Contractor shall make sure that the new rating withstands the available short circuit current.

H.20.2.3 Control Panel

Equipment indicated on plan as control panel (CP, ECP) of individual air handler units belonging to chilled water air conditioning system, shall consist of individually mounted combination starters and shall also include all additional control and instrumentation devices as described under corresponding clause in mechanical section.

Individually Mounted Combination Starter

Combination Starters shall comprise motor starters as specified hereinbefore and a molded case circuit breaker for motors 15 Hp and above, and miniature circuit breaker for motors smaller than 15 Hp. in an IP40 enclosure unless otherwise indicated. The circuit breaker may be a magnetic only type in lieu of thermal magnetic to the approval of the Engineer.

H.20.2.4 Solid-State Reduced Voltage Motor Starter (Soft Starter)

Solid state, soft starter shall be used where indicated on drawings and shall be quoted separately as an alternative to star-delta starter.

- The solid-state reduced voltage motor controller shall consist of a power section, a one-piece printed circuit logic board and a field wiring interface terminal board.
- The power section shall be three-phase, 50 Hz. and rated for the hp, current, and voltage as shown on the Contractor's approved shop drawings. It shall consist of three sets of back-to-back phase controlled power semi-conductors. Maximum current limit shall be 500% for standard units.
- Resistor/Capacitor snubber networks shall be used to prevent false firing of SCR'S due to dv/dt characteristics of the system.
- Fan cooled units shall be supplied with thermal sensors on the heat sink to trip the control protective logic for over- temperature condition. Thermal sensors shall be rated 90 °C maximum.
- The one piece logic board shall be mounted for easy testing, service and replacement.
- three-phase current sensing via current transformers for closed loop control to insure motor stability shall be provided.
- The logic board shall used quick disconnect plug-in connectors for current transformer inputs, line-and-load voltage inputs, SCR gate firing output circuits and status panel.
- The logic circuitry shall include as a minimum: a. Short circuit electronic trip over current protection. Time not to exceed ½ cycle. b. Inverse time running over current protection. c. Auxiliary trip circuitry. d. Gate firing circuit lockout protection on trip. e. Fault relay lockout protection. f. 250%-500% current limit adjustment.

g. Minimum and maximum voltage adjustments. h. Voltage stability adjustment.

- The logic board soldering shall be treated with a conformal protective coating system.
- The logic board shall include, as standard, current and motor slip sensing circuitry that continually monitor motor load and regulate motor voltage to minimize motor kWh energy consumption.
- The solid-state logic shall provide phase sequence protection.
- External interface circuitry shall include 230-volt relay logic interface capability.
- Tripped functions shall be designed to be cleared by removing power from the solid-state logic board.
- Controllers for motors larger than 200 hp shall have additional features as follows: a. well time at current limit with ramp continuation after acceleration. b. Individual light emitting diodes (LEDs) to indicate run, under voltage, phase loss, phase current unbalance, over current trip, over temperature, current limit, and of ramp and incorrect phase rotation c. Single-phase protection with built-in short time delay. d. Under voltage protection with built-in short time delay. e. The power section shall have metal oxide varistor (MOV) type surge suppressors across the SCRs rated 10% above the SCR rated voltage. The power semi-conductors shall be rated with peak inverse voltage at least 2.5 times SCR rated line-to-line voltage. Data shall be made available on tolerances to incoming line voltage surges or line spikes. Data shall include both magnitude and time content of each spike

(voltage peaks and volt-seconds) plus tolerance to repetitive surges. f. 100%-120% full load running current trip adjustment. g. 200%-500% current limit adjustment .

- Two ground lugs shall be furnished, one for incoming and one for outgoing ground connections.
- Power terminations shall consist of pressure type terminals for top or bottom entrance.
- Enclosure a. Enclosures shall not be less than 16-gauge steel. Type 12 enclosures shall be of welded construction with gasketed heat sink and doors. b. Doors shall include plastic device holders for mounting up to six (eight for above 200 hp motors) operator devices. c. External and internal steel surfaces to be painted shall be thoroughly cleaned and phosphatized prior to application of paint. They shall then be primed with a corrosion-resisting coating. Cabinet and door finish shall be manufacturer's standard. d. Controllers for motors above 200 hp shall include the following: 1. The operating handle of the disconnect-when supplied- shall always remain connected to the breaker or switch. The operating handle shall not be mounted on the door of the enclosure, but on the controller for safe "stand - aside" operation. The position of the operating handle will indicate ON or OFF position of switch or circuit breaker and include provision for padlocking in the OFF position. 2. Interlock provisions shall prevent unauthorized opening or closing of the starter door with the disconnect in the ON position. 3 The structure, when floor-mounted, shall be provided with adequate lifting means and shall be capable of being rolled or lifted into installation position and bolted to the floor. 4. A door-mounted status panel shall provide individual light emitting diodes (LEDs) to indicate run, under voltage, phase over temperature, current limit, end of ramp and incorrect phase rotation.

H.20.2.5 Motor Starters, General

Motor starters shall be in accordance with the requirements of the IEEE, NEC, NEMA (ICS 1, ICS 1.1, ICS 2, ICS 6, ICS 7 and ICS 7.1) and UL.

Shall have the following features:

- Separately enclosed unless part of another assembly.
 - Circuit breakers and safety switches within the motor controller enclosures shall have external operating handles with lock-open padlocking provisions and shall indicate the ON and OFF positions.
 - Motor control circuits: a. Shall operate at not more than 230 volts. b. Shall be grounded except as follows: 1) Where isolated control circuits are shown. 2) Where manufacturers of equipment assemblies recommend that the control circuits be isolated.
- c. Incorporate a separate, heavy duty, control transformer within each motor controller enclosure to provide the control voltage for each motor operating over 230 volts. d. Incorporate over current protection for both primary and secondary windings of the control power transformers in accordance with the NEC.
- Overload current protective devices: a. Overload relay (thermal or induction type. b. Overload relay (solid state type. c. One for each pole. d. Manual reset on the door of each motor controller enclosure. e. Correctly sized for the associated motor's rated full load current. f. Check every motor controller after installation and verify that correct sizes of protective devices have been installed. g. Deliver four copies of a summarized list to the Resident Engineer which indicates and adequately identifies every motor controller installed. Include the catalog numbers for the correct sizes of protective devices for the motor controllers.
 - A) switch is required unless specifically stated in the Schedules and BOQ as not required for a particular starter. H- O-A switch is not required for manual motor starters.

- Incorporate into each control circuit a 230-volt, solid state time delay relay (ON delay), minimum adjustable range from 0.3 to 10 minutes, with transient protection. Time delay relay is not required where H-O-A switch is not required.
- Auxiliary contacts, pilot lights, pushbuttons and other devices and accessories as shown on the Contractor's approved shop drawings or otherwise required.
- Enclosures: Shall be the NEMA types shown on the Contractor's approved shop drawings for the motor controllers. b. Shall be the NEMA types which are the most suitable for the environmental conditions where the motor controllers are being installed. c. Doors mechanically interlocked to prevent opening unless the breaker or switch within the enclosure is open. d. Enclosures shall be primed and finish coated at the factory with the manufacturer's prime coat and standard finish.

Motor controllers incorporated with equipment assemblies shall also be designed for the specific requirements of the assemblies.

For motor controllers being installed in existing motor control centers or panel boards, coordinate with the existing centers or panel boards.

Additional requirements for specific motor controllers, as indicated in other sections, shall also apply.

Provide a disconnecting means or safety switch near and within sight of each motor.

Refer to paragraph, MOTOR CONTROL STATIONS, in this section for additional requirements.

H.20.2.6 Manual Motor Starters

Shall be in accordance with applicable requirements of 2.1 above.

Manual motor starters.

- Starters shall be AC, general-purpose Class A, and manually operated type with full voltage controller for induction motors, rated in horsepower.
- Units shall include overload // and low voltage // protection, red pilot light, // NO // NC // auxiliary contact // and toggle operator.

Fractional horsepower manual motor starters.

- Starters shall be AC, general-purpose Class A, manually operated with full voltage controller for fractional horsepower induction motors.
- Units shall include thermal overload protection, red pilot light and toggle operator.

Motor starting switches.

- Switches shall be AC, general-purpose Class A, and manually operated type with full voltage controller for fractional horsepower induction motors.
- Units shall include thermal overload protection, red pilot light // low voltage protection //, // NO // NC // auxiliary contact // and toggle operator.

H.20.2.7 Across-The-Line Controllers

Manual Controller: NEMA ICS 2, general purpose, Class A, with toggle action and overload element.

Magnetic Controller: NEMA ICS 2, Class A, full voltage, non-reversing, across the line, unless otherwise indicated.

- Control Circuit: 230 V; obtained from integral control power transformer with a control power transformer of sufficient capacity to operate connected pilot, indicating and control devices, plus 100 percent spare capacity.
- Overload Relay: Ambient-compensated type with inverse-time-current characteristic and NEMA ICS 2, Class 10 tripping characteristic. Provide with heaters or sensors in each phase matched to nameplate full-load current of specific motor to which they connect and with appropriate adjustment for duty cycle.
- Adjustable Overload Relay: Dip switch selectable for motor running overload protection with NEMA ICS 2, Class 10 tripping characteristic, and selected to protect motor against voltage and current unbalance and single phasing. Provide relay with Class II ground-fault protection, with start and run delays to prevent nuisance trip on starting.

H.20.2.8 Reduced-Voltage Controllers

Star-Delta Controller: NEMA ICS 2, closed transition with adjustable time delay.

Part-Winding Controller: NEMA ICS 2, closed transition with separate overload relays for starting and running sequences.

Autotransformer Reduced-Voltage Controller: NEMA ICS 2, closed transition

Solid-State, Reduced-Voltage Controller: NEMA ICS 2, suitable for use with NEMA MG 1, Design BT polyphase, medium induction motors.

- Adjustable acceleration rate control utilizing voltage or current ramp, and adjustable starting torque control with up to 500 percent current limitation for 20 seconds.
- Surge suppressor in solid-state power circuits providing 3-phase protection against damage from supply voltage surges 10 percent or more above nominal line voltage.
- LED indicators showing motor and control status, including the following conditions: a. Control power available. b. Controller on. c. Overload trip. d. Loss of phase. e. Shorted silicon-controlled rectifier. f. Ground fault relay.
- Automatic voltage-reduction controls to reduce voltage when motor is running at light load.
- Motor running contactor operating automatically when full voltage is applied to motor.

H.20.2.9 Multispeed Controllers

Multispeed Controller: Match controller to motor type, application, and number of speeds; include the following accessories:

- Compelling relay to ensure that motor will start only at low speed.
- Accelerating relay to ensure properly timed acceleration through speeds lower than that selected.
- Decelerating relay to ensure automatically timed deceleration through each speed.

H.20.2.10 Variable Speed Motor Controllers

Shall be in accordance with applicable portions of 2.1 above.

Shall be solid state, micro processor-based with adjustable frequency and voltage, three phase output capable of driving standard NEMA B design, three phase alternating current induction motors at full rated speed. The drives shall utilize a full wave bridge design incorporating diode rectifier circuitry with pulse width modulation (PWM). Other control techniques are not acceptable. Silicon controlled rectifiers (SCR) shall not be used in the rectifying circuitry. The drives shall be designed to be used on variable torque loads and shall be capable of providing sufficient torque to allow the motor to break away from rest upon first application of power.

Shall be rated for input power of 400 volts, three phase, 50 HZ. Unit shall be capable of operating within voltage parameters of plus 10 to minus 10 percent of line voltage, and be suitably rated for the full load amps of the maximum watts (HP) within its class.

Each controller shall be factory tested at maximum watts (HP), rated full load current and at an ambient temperature of 40 degrees C for a period of not less than 24 hours. If a component fails, it shall be replaced and the test restarted for the full time period. A certified copy of the factory Test Report shall be furnished to the Resident Engineer prior to shipping the controller to the job site.

Controllers shall have the following features:

- Isolated power for control circuits.
- Manually re-settable motor overload protection for each phase.
- Adjustable current limiting circuitry to provide soft motor starting. Maximum starting current shall not exceed 200 percent of motor full load current.
- Independent acceleration and deceleration time adjustment, manually adjustable from 2 to 30 seconds. (Set timers to the equipment manufacture's recommended time in the above range.)
- Provide 4 to 20 ma current follower circuitry for interface with mechanical sensor devices.
- Provide circuitry to initiate an orderly shutdown when any of the conditions listed below occur. The controller shall not be damaged by any of these electrical disturbances and shall automatically restart when the conditions are corrected: a. Incorrect phase sequence. b. Single phasing. c. Over voltage in excess of 10 percent. d. Under voltage in excess of 10 percent. e. Running over current above 110 percent (shall not automatically reset for this condition.) f. Instantaneous over current above 150 percent (shall not automatically reset for this condition). g. Surge voltage in excess of 1000 volts. h. Short duration power outages of 12 cycles or less (i.e., distribution line switching, generator testing, automatic transfer switch operations.)
- Provide automatic shutdown on receipt of a power transfer warning signal from an automatic transfer switch. Controller shall automatically restart motor after the power transfer.

Minimum efficiency shall be 95 percent at 100 percent speed and 85percent at 50 percent speed.

The displacement power factor of the controller shall not be less than 95 percent under any speed or load condition.

Controllers shall include a door interlocked fused safety disconnect switch or door interlocked circuit breaker switch which will disconnect all input power.

Include a by-pass starter with circuitry to protect and isolate the variable speed controller. When the variable speed controller is in the by-pass mode, the solid-state components shall be isolated from the power supply on both the line and motor side.

The following accessories are to be door mounted:

- AC Power on light.
- Ammeter (RMS motor current).
- HAND-OFF-AUTOMATIC switch.
- Manual speed control in HAND mode.
- System protection lights indicating that the system has shutdown and will not automatically restart.
- System protection light indicating that the system has shutdown but will restart when conditions return to normal.
- Manual variable speed controller by-pass switch.

- Diagnostic shutdown indicator lights for each shutdown condition.
- Provide two N.O. and two N.C. dry contacts rated 230 volts, 10 amperes, 50 HZ for remote indication of the following: a. System shutdown with auto restart. b. System shutdown without auto restart.
- Incorporate into each control circuit a 230-volt, time delay relay (ON delay), adjustable from 0.3-10 minutes, with transient protection. Provide transformer/s for the control circuit/s.
- Controller shall not add any current or voltage transients to the input AC power distribution system nor shall the controller be affected by transients from other devices on the AC power distribution system. Controllers shall be protected to comply with IEEE C37.90.1 and UL-508. Line noise and harmonic voltage distortion shall not exceed the values allowed by IEEE 519.

H.20.2.11 Motor Control Stations

Shall have the following features:

- Designed for suitably fulfilling the specific control functions for which each station is being installed.
- Coordinate the use of momentary contacts and maintained contacts with the complete motor control systems to insure safety for people and equipment.
- Each station shall have two pilot lights behind red and green jewels and a circuit to its motor controller. Connect the lamps so they will be energized as follows: a. Red while the motor is running. b. Green while the motor is stopped.
- Where two or more stations are mounted adjacent to each other, install a common wall plate, except where the designs of the stations make such common plates impracticable.
- Identify each station with a permanently attached individual nameplate, of laminated black phenolic resin with a white core and engraved lettering not less than 6 mm (1/4-inch) high. Identify the motor by its number or other designation and indicate the function fulfilled by the motor.

Components of Motor Control Circuits:

- Shall also be designed and arranged so that accidental faulting or grounding of the control conductors will not be able to start the motors.
- Use of locking type STOP pushbuttons or switches, which cause motors to restart automatically when the pushbuttons or switches are released, will not be permitted.

H.20.3 Execution

H.20.3.1 Installation

Install motor control equipment in accordance with manufacturer's recommendations, the NEC, NEMA and as shown on the Contractor's approved shop drawings.

Install Variable Speed Motor Controllers in accordance with manufacturers recommendations, the NEC, as shown on the Contractor's approved shop drawings and in accordance with NEMA ICS 7.1.C.

Furnish and install heater elements in motor starters to match the installed motor characteristics.

H.20.3.2 Spare Parts

Two weeks prior to the final inspection, provide one complete set of spare fuses (including heater elements) for each starter/controller installed on this project.

H.21. MOTORS

H.21.1 General

H.21.1.1 Description

This section specifies the furnishing, installation and connection of motors.

H.21.1.2 Related Work

BASIC ELECTRICAL MATERIALS AND METHODS: General electrical requirements that are common to more than one Section.

MOTOR STARTERS: Starters, control and protection for motors.

MOTOR STARTERS: Multiple motor control assemblies, which include motor starters.

H.21.1.3 Submittals

In accordance with Section BASIC ELECTRICAL MATERIALS AND METHODS, submit the following:

Shop Drawings:

- Sufficient information, clearly presented, shall be included to determine compliance with drawings and specifications.
- Include electrical ratings, dimensions, mounting details, materials, horsepower, RPM, enclosure, starting characteristics, torque characteristics, code letter, full load and locked rotor current, service factor, and lubrication method.

Manuals:

- Submit simultaneously with the shop drawings, companion copies of complete maintenance and operating manuals, including technical data sheets and application data.

Certification: Two weeks prior to final inspection, unless otherwise noted, submit four copies of the following certification to the Resident Engineer:

- Certification that the motors have been properly applied, installed, adjusted, lubricated, and tested.

H.21.1.4 Applicable Publications

Publications listed below (including amendments, addenda, revisions, supplements and errata) form a part of this specification to the extent referenced. Publications are referenced in the text by designation only.

National Electrical Manufacturers Association (NEMA):

- MG 1-98 Motors and Generators
- MG 2-01 Safety Standard and Guide for Selection, Installation and Use of Electric Motors and Generators

National Fire Protection Association (NFPA):

- 70-02 National Electrical Code (NEC)

H.21.2 Products

H.21.2.1 Motors

For alternating current, fractional and integral horsepower motors, IEC 34 Standards, IEC 72, Standard and NEMA Publications MG 1 and MG 2 shall apply.

Voltage ratings shall be as follows:

- Single phase: a. Motors connected to 230-volt systems: up to 0.75 HP unless otherwise noted.
- Three phase: a. Motors connected to 400-volt systems larger than 0.75HP .

Horsepower ratings shall be adequate for operating the connected loads continuously in the prevailing ambient temperatures in areas where the motors are installed, without exceeding the NEMA standard temperature rises for the motor insulation.

Motor designs, as indicated by the NEMA code letters, shall be coordinated with the connected loads to assure adequate starting and running torque.

Motor Enclosures:

- Shall be the NEMA types shown on the Contractor's approved shop drawings for the motors.
- Where the types of motor enclosures are not shown on the Contractor's approved shop drawings, they shall be the NEMA types, which are most suitable for the environmental conditions where the motors are being installed.
- Enclosures shall be primed and finish coated at the factory with manufacturer's prime coat and standard finish.

Additional requirements for specific motors, as indicated in other sections, shall also apply.

Energy-Efficient Motors (Motor Efficiencies): All permanently wired polyphase motors of 746 Watts or more shall meet the minimum full-load efficiencies as indicated in the following table, and as specified in this specification. Motors of 746 Watts or more with open, drip-proof or totally enclosed fan-cooled enclosures shall be NEMA premium efficiency type, unless otherwise indicated. Motors provided as an integral part of motor driven equipment are excluded from this requirement if a minimum seasonal or overall efficiency requirement is indicated for that equipment by the provisions of another section.

Minimum Efficiencies Open Drip-Proof				Minimum Efficiencies Totally Enclosed Fan-Cooled			
Rating W(HP)	1200 RPM	1800 RPM	3600 RPM	Rating (HP)	1200 RPM	1800 RPM	3600 RPM
0.746 (1)	82.5%	85.5%	77.0%	0.746 (1)	82.5%	85.5%	77.0%
1.12 (1.5)	86.5%	86.5%	84.0%	1.12 (1.5)	87.5%	86.5%	84.0%
1.49 (2)	87.5%	86.5%	85.5%	1.49 (2)	88.5%	86.5%	85.5%

2.24 (3)	88.5%	89.5%	85.5%	2.24 (3)	89.5%	89.5%	86.5%
3.73 (5)	89.5%	89.5%	86.5%	3.73 (5)	89.5%	89.5%	88.5%
5.60 (7.5)	90.2%	91.0%	88.5%	5.60 (7.5)	91.0%	91.7%	89.5%
7.46 (10)	91.7%	91.7%	89.5%	7.46 (10)	91.0%	91.7%	90.2%
11.2 (15)	91.7%	93.0%	90.2%	11.2 (15)	91.7%	92.4%	91.0%
14.9 (20)	92.4%	93.0%	91.0%	14.9 (20)	91.7%	93.0%	91.0%
18.7 (25)	93.0%	93.6%	91.7%	18.7 (25)	93.0%	93.6%	91.7%
22.4 (30)	93.6%	94.1%	91.7%	22.4 (30)	93.0%	93.6%	91.7%
29.8 (40)	94.1%	94.1%	92.4%	29.8 (40)	94.1%	94.1%	92.4%
37.3 (50)	94.1%	94.5%	93.0%	37.3 (50)	94.1%	94.5%	93.0%
44.8 (60)	94.5%	95.0%	93.6%	44.8 (60)	94.5%	95.0%	93.6%
56.9 (75)	94.5%	95.0%	93.6%	56.9 (75)	94.5%	95.4%	93.6%
74.6 (100)	95.0%	95.4%	93.6%	74.6 (100)	95.0%	95.4%	94.1%
93.3 (125)	95.0%	95.4%	94.1%	93.3 (125)	95.0%	95.4%	95.0%

112 (150)	95.4%	95.8%	94.1%	112 (150)	95.8%	95.8%	95.0%
149.2 (200)	95.4%	95.8%	95.0%	149.2 (200)	95.8%	96.2%	95.4%

Minimum Power Factor at Full Load and Rated Voltage: 90 percent at 1800 RPM

Premium efficiency motors shall be used where energy cost/kW x (hours use/year) > 50.

H.21.3 Execution

H.21.3.1 Installation

Install motors in accordance with manufacturer's recommendations, the NEC, NEMA, as shown on the Contractor's approved shop drawings and/or as required by other sections of these specifications.

H.21.3.2 Field Tests

Megger all motors after installation, before start-up. All shall test free from grounds.

H.22. OVER CURRENT PROTECTIVE DEVICES

H.22.1 General

H.22.1.1 Description

General:

- Furnish all labour, materials, tools, equipment, and services for over current protective devices, in accord with provisions of Contract Documents.
- Completely coordinate with the work of other trades.
- Although such work is not specifically indicated, furnish and install all supplementary or miscellaneous items, appurtenances and devices incidental to or necessary for a sound, secure and complete installation.
- See Section, for General Requirements.

Related work specified elsewhere:

- General Requirements.
- General Provision for Electrical Work.
- Switchboards (main distribution boards)
- Panel Boards
- Motor Control Equipment

H.22.1.2 Submittals

- Shop drawings: As indicated for equipment using devices.
- Product data: As indicated for equipment using devices.
- Samples: Required for Client and/or Engineer's review.
- Project information: Required for Client and/or Engineer's review.
- Contract closeout information: Required for Client and/or Engineer's review.

H.22.2 Products

H.22.2.1 General

Equipment and devices by same manufacturer.

H.22.2.2 Circuit Breakers

Moulded case type: Unit construction, quick make, quick break, manual and automatic operation, 3 position "on" "off" and "tripped". "Tripped" condition clearly indicated. All poles open and close simultaneously 10,000 AIC minimum.

- Thermal magnetic type providing inverse time overload and instantaneous short circuit protection by means of a thermal magnetic element. Interchangeable trip where indicated.
- Solid State trip type providing inverse time overload, adjustable instantaneous short circuit, and short time delay protection by means of a solid state trip element with associated current monitors and flux transfer shunt trip. Provide interchangeable rating plug and push-to-trip button. Built-in adjustable ground fault protection where indicated.
- Current-limiting type providing inverse time overload, instantaneous short circuit, and current- limiting protection.

Insulated case type providing adjustable inverse time overload, adjustable instantaneous short circuit, adjustable short time delay, and adjustable ground fault protection by means of a solid state trip element with two-steps stored energy mechanism. Provide interchangeable rating plug. Rate for application at 100 percent of frame size.

- Electrically operated where indicated. Provide motor driven operator for charging mechanism with open, close and charge push buttons.
- Make manually operated breakers field convertible to electrically operated by adding the motor operator.
- Draw-out construction where indicated. Roll out type operated by removable crank handle. Interlock with door.

Air type providing adjustable inverse time overload, adjustable instantaneous short circuit, adjustable short time delay, and adjustable ground fault protection by means of a solid state trip element with two-step stored energy mechanism. Provide interchangeable sensor element. Rate for application at 100 percent of frame size.

- Current-limiting type where indicated. Provide 200,000 AIC with current-limiting fuses in series with breaker.
- Electrically operated where indicated. Provide motor driven operator for charging mechanism with open and close push buttons.
- Draw-out construction where indicated. Roll out type operated by removable crank handle. Interlock with door.

Motor circuit protector providing adjustable instantaneous short circuit protection only by means of a magnetic or solid state trip element.

- Moulded case construction.
- Current-limiting where indicated or required providing 200,000 AIC by means of a current-limiter attachment.

H.22.2.3 Fusible Switches

Panelboard type suitable for mounting in switchboards or panelboards as indicated. Ground fault protection system where indicated. Provide current sensor, shunt trip and control power transformer.

H.22.3 Execution

H.22.3.1 Installation

Install in switchboards, panelboards and motor control centers as indicated in those sections.

Install individually enclosed as specified in other sections or indicated. Use IP-44 enclosure unless shown otherwise.

H.23. MOTOR CONTROL EQUIPMENT

H.23.1 General

H.23.1.1 Description

General:

- Furnish all labour, materials, tools, equipment, and services for motor control equipment, in accord with provisions of Contract Documents
- Completely coordinate with the work of other trades
- Although such work is not specifically indicated, furnish and install all supplementary or miscellaneous items, appurtenances and devices incidental to or necessary for a sound, secure and complete installation

Related work specified elsewhere:

- General Provisions for Electrical Work
- General requirements

H.23.1.2 Submittals

Shop drawings:

- Outline drawings of assembly
- One line diagrams and wiring diagrams for assembly and components
- Interconnection wiring diagrams

Product data:

- Complete catalog information

Contract closeout information: Operating and maintenance data

H.23.2 Products

H.23.2.1 Materials

All goods and products covered by these specifications shall be submitted for Engineer's prior approval to confirm the compliance of these goods and products with the requirements set in these Specifications including.

Motors:

- Verify all motor sizes and types of control from approved mechanical shop drawings
- Motors 1 KW and above: unless otherwise indicated, shall be 400 V, three phase, 50 cycle, provide 3 phase combination magnetic starters.
- Motors below 1 KW: unless otherwise indicated, shall be 230 V, single phase, 50 cycle, provide manual thermal element units.

Motor control centers: Standard Construction, cubicle type.

- Service voltage: 400 V, 3 phase, 50 cycle.
- Control voltage: 230 V, utilizing individual 400/230 V control transformers.

- Provide each circuit with suitable phenolic nameplate with white cut letters to designate purpose of circuit.
 - Finish: Thoroughly clean each structure inside and out after fabrication and apply primer coat, and two coats of light grey enamel, inside and out.
 - Structure units: Totally enclosed, free-standing type with structures joined together to form one assembly of IP-54.
 - a. Fabricate of not less than 1.5 mm steel, with 2 mm steel doors, in standardized units.
- b. Design so that units may be readily removed or future structures added as required.
- c. Provide each structure with two horizontal wiring spaces, one at top and one at bottom, which will line up with adjacent units to form convenient wiring raceway entire length of control center.
- d. Provide each structure with vertical wiring space between starter cell and side sheet for unit wiring, equipped with cable tie supports to hold cables and wiring in place.
- e. Bottom shall have ample unrestricted space for conduit and feeder entry.
- f. Doors: Formed round corners, rolled edges, neoprene gaskets, and at least two heavy duty hinges, held closed by means of quick-captive fasteners.
- g. Fabricate doors as part of structure and not part of starter, to cover openings after starters have been removed.
- h. Provide main horizontal bus, rated as indicated, across top of each structure; full capacity, full-length with provisions for extension.
- i. Bus bars: High-conductivity copper of rectangular cross section; support in each structure by means of bus supports.
- j. Provide each structure with vertical 6 mm x 50 mm minimum, copper bus to distribute incoming power to each fusible switch and starter in structure.
- k. Brace bussing for 22,000 RMS symmetrical amperes minimum, or greater where indicated.
- l. Provide continuous 6 mm x 25 mm copper, ground bus solidly grounded to each structure near bottom and solidly grounded to cold water metallic piping system Provide main lugs only or main protective device as indicated.
- Fusible switch and linestarter units: Built-in interchangeable modular height combinations:
 - a. Line plug-in, pull-out, lock-out type.
 - b. Provide guides in structure for supporting and aligning unit starter during removal or replacement.
 - c. Lock-out latch to enable electrician to padlock unit in "pull-out" position and at same time isolate stubs and entire unit from bus Hold each unit in place by means of quick-captive fasteners.
 - d. Ventilated so that it can be located anywhere within structure using same overload heaters for same load.
 - e. Fuse clips: Positive pressure type accommodating time delay or current limiting fuses of ratings indicated.
 - f. Operating handle shall clearly indicate whether switch is ON, OFF, or TRIPPED.
 - g. Provide means to lock each switch handle in OFF position with cover closed by means of one to three padlocks.
 - h. Interlock so that switch must be in OFF position before door can be opened.
- Safety switches: Visible blades and quick-make, quick-break operating mechanism
- Provide safety switch at motor location where indicated or required by IEC standards.
- Single speed and reduced voltage starters :
- Provide with three overload relays for complete single-phasing and overload protection.

- Provide START-STOP push button station or selector switch and red pilot light, or pilot light only, for each motor starter on cover of each unit where indicated on drawings or schedules.
- Provide with two extra NO interlocking contacts in addition to seal-in contacts.

Combination full voltage starters: Fusible switch type

- External manual reset thermal overload relays, low-voltage protection and fusible switch/circuit breaker short-circuit protection.

Combination reduced voltage starters: Circuit breaker type

- Direct on line for motors up to 15 kw.
- Use star-delta starter for motor rating from 16 up to 50 kw.
- Use soft starter for motors rating more than 50 kw.

Combination starters for 2 speed, one or two winding motors:

- Coordinate starter characteristics with specified motor requirements from approved Motor Shop Drawings.
- Provide with six overload relays for complete single-phasing and overload protection.
- Provide with HIGH/LOW/OFF/AUTO selector switch and two red pilot lights labeled HIGH and LOW for each motor starter on cover of each unit.
- Provide with two extra NO interlocking contacts per starter coil in addition to seal-in contacts.
- Provide adjustable 0-30 second time delay relay to provide delay in energization when switching from high to low speed Set at 20 seconds.

Overload relays: All overload relays shall be bimetallic type.

Motor control for separately mounted starter:

- Provide safety switch and line voltage motor control station, unless otherwise indicated.
- Provide safety switch ahead of motor control, of size and where indicated, or required by standards. Separately-mounted motor control stations: Heavy-duty type, push button and selector switch with IP-54 enclosure flush mounted only where indicated.

H.23.3 Execution

H.23.3.1 Installation

Install as indicated and in accord with manufacturer's recommendations and instructions

Provide 100 mm high minimum concrete pad under each motor control center:

- Install two 100 mm channel iron sills flush in pads to support and maintain alignment of each motor control center.
- See Section, for concrete.

Coordinate with the building automation and management system works.

H.24. AUTOMATIC TRANSFER SWITCHES

H.24.1 General

H.24.1.1 Description

General:

- Furnish all labour, materials, tools, equipment, and services for automatic transfer switches, in accord with provisions of Contract Documents.
- Completely coordinate with the work of other trades.
- Although such work is not specifically indicated, furnish and install all supplementary or miscellaneous items, appurtenances and devices incidental to or necessary for a sound, secure and complete installation.

Related work specified elsewhere:

- General Provisions for Electrical Works
- Medium Voltage Engine Generating Set
- General requirements

H.24.1.2 Submittals

Shop drawings:

- Outline drawings of assembly.
- One line diagrams and wiring diagrams for assembly and components.
- Interconnection wiring diagrams.

Product data:

- Complete catalog information.

Contract closeout information:

- Operating and maintenance data.

H.24.2 Products

H.24.2.1 Materials

Automatic transfer switches: Electrically operated mechanically held 3 phase AC, air- circuit breaker type, similar to breaker in 20 KV switchgear, with supervisory relays on each phase of normal source and supervisory frequency/voltage relay for emergency source.

- The transfer switch shall be suitable for all classes of loads to 3300 Volts , 3 phase,
- 50 HZ AC power, when enclosed in an unventilated sheet metal enclosure major component of equipment shall have Manufacturer's name, address, type & style and catalogue number on a plate.
- Adjust normal source supervisory relays to transfer load if voltage on any phase drops below 70 percent of normal and to restore load to normal source when normal source voltage on all phases is 90 percent or more.
- Obtain voltage for main contact operating solenoid from source to which load is being transferred.
- All transfer switches serving line to neutral load(s) shall be 4 - pole switches or shall have overlapping neutral contacts Transfer switches serving strictly line to line load(s) shall be 3 pole switches 400/230 volts.

- Make mechanical design of switch such that it will positively open all ungrounded conductors from normal source before connection is made to alternate source and will positively open alternate source before connection is made to normal source.
- Design mechanical interlock so it cannot be readily disabled, disconnected, improperly adjusted, removed or otherwise made inoperative.
- Switch shall have provisions for visual inspection of switch blades and contacts.
- Silver surface main contacts and protect by arcing contacts.
- Make all contacts and coils readily accessible for replacement from front of panel without major disassembly.
- Provide red and green indicating lights with fuses, identification nameplates, and test switch on front to simulate normal power failure at switch.
- Rate each individual switch as indicated.
- Provide written approval from the Local Electric Company .Ensure that there can be no parallel operation between SEC power and power for emergency generator.
- Provide engine starting contacts and all other auxiliary contacts and accessory devices for functions to be performed.
- Provide time delay on engine start, field adjustable from 0 to 10 SEC., by SEC, and factory set at 4 SEC., to avoid unnecessary starting caused by short time outages.
- Provide time delay on retransfer to normal, field adjustable from 2 to 30 minutes, by minute, and factory set to avoid erratic operation caused by short time reestablishment of normal source.

Operation of Automatic Transfer Switch

Switch shall be arranged to start the generator automatically if normal source voltage falls below 70% of nominal Provide an adjustable time delay of 0 to five (5) minutes on engine shutdown in the switch These time delays shall operate only after retransfer to normal Include a Voltmeter mounted in the trim of switch, wired across two of the generator phases Sensing relays shall operate without contact chatter or false response when voltage is slowly varied to dropout and pickup levels Four auxiliary contacts shall be provided: Two for switch position indicating use, mounted on same shafts with main contacts; two auxiliary contacts, one normally open and one normally closed, shall operate after completion of the 3 second override delay All auxiliary contacts shall have 10 ampere minimum continuous contact rating.

H.24.3 Execution

H.24.3.1 Installation

The Automatic Transfer Switches shall be free standing type and located as shown on the Contractor's approved shop drawings.

Connect as indicated in one line diagram.

H.24.3.2 Start-Up Instructions

On completion of the installation, the initial start-up shall be performed by a factory trained service representative together with the engine suppliers representative Service representative shall demonstrate and test the ability of the engine control, automatic transfer switch, and handover a list of manuals, operating instructions, wiring diagrams for all equipments

H.25. INTERIOR LIGHTING

H.25.1 General

H.25.1.1 Description

General:

- Furnish all labour, materials, tools, equipment, and services for interior lighting in accordance with provisions of contract documents.
- Completely co-ordinate with the work of other trades.
- Furnish and install all supplementary or miscellaneous items, appurtenances and devices incidental to or necessary for a sound, secure and complete installation.
- Unless otherwise specified, fixtures are to be manufacturers' standard series, designed and manufactured generally in accordance with the schedule of lighting fixture and complying with IEC 598.

Related work specified elsewhere:

- General Provisions for Electrical Work.
- General requirements

H.25.1.2 Applicable Codes and Standards

The following codes and standards are intended to provide an acceptable level of quality for materials and products. The Contractor may propose alternative code and standards providing they give an equivalent degree of quality as the referenced codes and standards and are submitted for Owner review and approval in advance of their use. All equipment furnished under these specifications shall conform to the appropriate standards of:

- NEC-National Electrical Code
- IEC: International Electrotechnical Commission
- IES-Illuminating Engineering Society
- ANSI-American National Standards Institute
- ASTM-American Society for Testing and Materials
- ASHREA / IESNA: American Society of Heating Refrigeration and Airconditioning Engineers 90.1 – 99.
- IECC: International Energy Conservation Code , 2000.

H.25.1.3 Submittals

Shop drawings: Required for Client review. Submit drawings for approval including, but not limited to the following:

- Exact position of each fixture on reflected ceiling plans, with indication of ceiling features, structural members, ducts, pipes and other fittings, as applicable and pertinent to the installation.
- Installation details including suspension and mounting provisions.
- Purpose made fixtures or lighting assemblies with full details.
- Wiring details, circuit and panelboard references, special lighting control arrangements, etc. Product data:
- Names of manufacturers, cuts and catalog numbers of all lighting fixtures to be used on project.
- Identify fixtures by Fixture Schedule number, including special notations for finishes, materials specification, colours, and mountings.

- Certified test data for LED light diffuser stating brightness and efficiency.
- Photometric performance curve for lighting calculations including polar light distribution curves, coefficient of utilization, glare classification, efficiency, depreciation factors, etc.

Samples: submit fully equipped sample of each fixture type together with colour and texture samples of each fixture.

- LED Lights
- Samples of all decorative/architectural lights.

Contract close out information

- Lens guarantee
- Operating and maintenance data.

H.25.1.4 Guarantee

Guarantee lenses in writing to the Client to provide satisfactory performance for 20 years without objectionable discoloration.

H.25.2 Products

H.25.2.1 Lighting Fixtures

All goods and products covered by these specifications shall be approved by the Client and conforming with the requirements of specifications. Procurement of all goods and products must be approved by the Client.

- All lighting fixtures and electrical components: shall be from renowned manufacturers who must have representative in Lebanon.
- Provide all recessed fixtures with gaskets of rubber, fibreglass, or equivalent material to prevent light leaks around flush trim.
- Provide standard plaster frame for all recessed lighting fixtures installed in plaster walls or ceilings. Design, finish and fabricate material to preclude possibility of rust stain in plaster.
- Lamps: As indicated on fixture schedule.
- Co-ordinate fixture types with ceiling construction.
- Provide pendant led fixtures with swivel hangers which will allow fixture to swing in any direction but will not permit stem to rotate.
- Swivel hangers for fixtures in mechanical equipment areas: Shock absorbing type.
- Pendant mounted, open, LED fixtures, not in continuous rows, shall be supported by conduit or by approved chains with cord and plug connection to ceiling mounted wistlock receptacle. Rigidly support continuous row pendant mounted LED fixtures with conduit and fasten fixtures to each other or mount on continuous metal channel similar to Unistrut. Provide reflector alignment clips on all industrial LED fixtures mounted in continuous rows.
- Provide antiglare shields for all compact LED lighting fixtures.
- Provide polished aluminum high reflectance reflectors for all downlights.
- The lighting power calculations (w/m2) have to be done according to the data of the chosen electronic ballast and lamps and submitted together with the related workshop drawing and material list for approval. The calculation results shall not exceed the limits of the lighting power allowances as defined by IECC and ANSI/ASHRAE/IESNA 90.1-2001/2002.

H.25.2.2 Exit Lights

Exit lights: 150 mm high letters on metal stencil background.

- Letter colour: Green (Arabic and English writings).
- Provide directional arrows as indicated on plans.
- Back wall mount.
- Universal mount, single face
- Universal mount, double face.
- Rechargeable battery for 1½ hours.

H.25.3 Execution

H.25.3.1 Installation

Fasten lighting fixtures supported by suspended ceiling systems to ceiling framing system with hold down clips.

Locate fixtures in accord with reflected ceiling plans.

Locate in exact center of tile when indicated. Relocate misplaced fixtures and replace damaged ceiling materials.

Provide access panels for recessed light fixtures that require access for maintenance when such access is not provided in design of fixture.

Contractor shall coordinate trim type recessed LED fixtures with reflected ceiling plans and/or room finished schedules prior to submittals.

Each security fixture attached to suspended ceiling system shall be attached with threaded bolt through ceiling to steel channel rigidly attached to ceiling suspension system.

Lighting in plant rooms is diagrammatic. Modify locations to suit conditions as approved.

Coordinate with the location of other ceiling fixtures according to architectural requirements.

Provide approved support for each lighting fixture outlet.

H.25.3.2 Adjust and Clean

Install fixtures level, aligned and parallel to building lines and at uniform heights. Make final height adjustment after installation.

Wipe all lighting fixture reflectors, lenses, lamps and trims, clean, after installation.

Replace all lamps operated during construction period with new lamps prior to final acceptance.

H.25.3.3 Inspection and Tests on Site

Visual inspection: Check neatness of installation, uniformity of equipment and nameplates etc.

Illumination measurements: To be taken at selected locations, to determine level and uniformity.

Operation: Check lighting installations for operation including control and regulation equipment.

Electrical data: Measure power factor, current and voltage at start for installations with discharge lamps.

H.26. EXTERIOR LIGHTING

H.26.1 General

H.26.1.1 Related Documents

General provisions for electrical work

General Requirements.

H.26.1.2 Applicable Codes and Standards

The following codes and standards are intended to provide an acceptable level of quality for materials and products. The Contractor may propose alternative code and standards providing they give an equivalent degree of quality as the referenced codes and standards and are submitted for Owner review and approval in advance of their use. All equipment furnished under these specifications shall conform to the appropriate standards of:

- NEC-National Electrical Code
- IEC: International Electrotechnical Commission
- IES-Illuminating Engineering Society
- ANSI-American National Standards Institute
- ASTM-American Society for Testing and Materials
- ASHREA / IESNA: American Society of Heating Refrigeration and Airconditioning Engineers 90.1 – 99.
- IECC: International Energy Conservation Code , 2000.

H.26.1.3 Summary

This Section includes exterior lighting fixtures, lamps, ballasts, poles standards, and accessories.

Related Sections: The following Sections contain requirements that relate to this Section:

- "Interior Lighting" for interior fixtures, lamps, ballasts, emergency lighting units, and accessories.

H.26.1.4 Definitions

Fixture: A complete lighting unit. Fixtures include a lamp or lamps and parts required to distribute the light, position and protect lamps, and connect lamps to the power supply.

Lighting Unit: A fixture, or an assembly of fixtures with a common support, including a pole or bracket plus mounting and support accessories.

Luminaire: LED fixture .

H.26.1.5 Submittals

General: Submit the following according to Conditions of Contract and related Specification Sections.

Product data describing fixtures, lamps, ballasts, poles, and accessories. Arrange product data for fixtures in order of fixture designation. Include data on features, poles, accessories, and the following:

- Outline drawings of fixtures and poles indicating dimensions and principal features.
- Electrical ratings and photometric data with certified results of independent laboratory tests.

- C. Shop and Construction drawings: submit drawings for approval including, but not limited to, the following: Layout of equipment in exact positions with mounting and construction details, concrete foundation dimensions and reinforcement, routing and sections of ductbanks and trenches, backfill and packing material, earthing rods etc. Cabling and wiring diagrams, single line drawings, loads, phase distribution, protection and control, earthing and the like.

Fixture Samples for Verification Purposes: A sample of each individual fixture type as instructed by the Owner.

Maintenance data for products for inclusion in Operating and Maintenance Manual specified.

H.26.1.6 Quality Assurance

Comply with IEC 598 and CISPR 15 for components and installation.

Technical Requirements: minor deviations from the drawings may be considered for improvement in construction details, but no changes are to be made without the written approval of the Owner.

Manufacturers' Qualifications: Firms experienced in manufacturing lighting units that are similar to those indicated for this Project and that have a record of successful in- service performance.

H.26.1.7 Storage and Handling of Poles

General: Store poles on decay-resistant treated skids at least 300 mm. above grade and vegetation. Support pole to prevent distortion.

Metal Poles: Retain factory-applied pole wrappings until just before pole installation.

For poles with nonmetallic finishes, handle with web fabric straps.

H.26.1.8 Warranty

Special Project Warranty: Submit a warranty, mutually executed by manufacturer and the Installer, agreeing to replace external parts of lighting fixtures exhibiting a failure of finish as specified below. This warranty is in addition to, and not a limitation of, other rights and remedies the Owner may have under the Contract Documents.

- Protection of Metal from Corrosion: Warranty against perforation or erosion of the finish due to weathering.
- Color Retention: Warranty against fading, staining, and chalking due to the effects of weather and solar radiation.
- Special Project Warranty Period: 5 years, beginning on the date of Substantial Completion.

H.26.1.9 Extra Materials

Furnish extra materials matching products installed as described below, packaged with protective covering for storage, and identified with labels describing contents. Deliver extra materials to the Owner.

The spare parts shall be not less than 15% for each type and rating installed Lamps: Lamps for each type and rating installed.

- Glass and Plastic Lenses, Covers, and Other Optical Parts: for each type and rating installed.
- Ballasts: for each type and rating installed.
- Globes and Guards: For each type and rating installed.

H.26.2 Products

H.26.2.1 Fixture Components, General

Metal Parts: Free from burrs and sharp edges and corners.

Sheet Metal Components: Corrosion-resistant aluminum, except as indicated. Form and support to prevent warping and sagging.

Housings: Rigidly formed, weather- and light-tight enclosures that will not warp, sag, or deform in use.

Doors, Frames, and Other Internal Access Provisions: Smooth operating, free from light leakage under operating conditions, and arranged to permit relamping without use of tools. Arrange doors, frames, lenses, diffusers, and other pieces to prevent accidental falling during relamping and when secured in the operating position. Provide for door removal for cleaning or replacing lens. Arrange for door opening to disconnect ballast.

Exposed Hardware Material: Stainless steel.

Plastic Parts: Resistant to yellowing and other changes due to aging and exposure to heat and UV radiation.

Lenses and Refractors: Materials as indicated. Use heat- and aging-resistant, resilient gaskets to seal and cushion lens and refractor mounting in fixture doors.

Mirror Reflectors: 99.5% purity, glazed and anodized aluminum or die-cast, super-purity aluminum vapour deposited, and coated with transparent layer of silicon protection against wiping.

Lamp Sockets: high grade porcelain, mounted in support brackets. Lamp support and locking system are to grip and prevent lamp movement in operation.

HRC Fuse Cartridges: suitably rated and conforming with IEC 269 or BS 88, are to be provided, complete with base, for protection of the luminaire. Fuse is to be rated to withstand starting current and is to be preferably located in control gear enclosure.

Terminal Blocks: suitable screw-tunnel type, clearly marked with arrangement to facilitate maintenance, quick replacement and easy disconnection of individual components.

H.26.2.2 Fixture Support Components

Columns; are to be circular section, tapered, formed sheet steel, electrically welded, and of height specified, Columns up to 12 m height are to be one piece section. Columns are to have Wall thickness of 3 mm at base. Sheet steel is to have minimum rupturing resistance of 37 kg/mm² and yield strength of 24 kg/mm².

Top of Column: is to be designed to receive single or double arm brackets or other arrangement required, to support number of luminaires shown on the Contractor's approved shop drawings. Bracket arrangement is to be designed to ensure that failure, due to wind induced oscillations, does not occur and that rotation from desired alignment is not possible.

Access Door: of weatherproof construction is to be positioned at column base and is to be suitably sized to insert and service the supply cable terminations and protective device. Door is to be flush fitting with retaining mechanism and positive locking arrangement with removable hexagonal key. Column is to be reinforced at door opening. Opposite each door, a non-hygroscope baseboard of suitable size to accept appropriate equipment is to be fixed to inside of column by purpose-made brackets. Stainless steel.

Metal Pole Grounding Provisions: Welded 1/2-inch threaded lug, accessible through handhole.

Steel Mast Arms: Fabricated from 2-inch pipe, continuously welded to pole attachment plate and having span and rise as indicated or required.

Metal Pole Brackets: Designed to match pole metal. Provide cantilever brackets without under brace, in the sizes and styles indicated, with straight tubular end section to accommodate the fixture.

H.26.2.3 Lamps

Provide fixtures with indicated number and type of lamps as shown on the Contractor's approved shop drawings and as described in section "Interior Lighting" where lamps are not indicated, provide lamps recommended by manufacturer.

H.26.2.4 Finish

Metal Parts: Manufacturer's standard finish except as otherwise indicated. Finish applied over corrosion-resistant primer, free of streaks, runs, holidays, stains, blisters, and similar defects. Remove poles, fixtures, and accessories showing evidence of corrosion or finish failure during Project warranty period and replace with new items.

Other Parts: Manufacturer's standard finish except as otherwise indicated.

H.26.2.5 Feeder Pillars

Equipment Housing: housing shall be to standards equivalent to BS 505: 1971, or approved equal fabricated from high grade aluminum sheet with thickness not less than 2mm. The sheet aluminum enclosure shall be coated with a thermosetting powder of an epoxy resin base modified by polyester resins. The enclosure shall be provided with a smooth finish and excellent protection against corrosion for 10 years maintenance free out-door use. It should also have excellent chemical protection properties against acid, salt, water and solvents. All other sheet metal should be hot dip galvanized in accordance with BS 729: 1986 or approved equal. The doors shall be Neoprene gasketed to IP55 of IEC 529. The gasket shall be adequate to maintain this protection at 60 degree C. ambient.

The enclosure shall have 4 louvers (ears) for diagonal ventilation. Prevention of the ingress of dust through louvers shall be provided to maintain the degree of protection.

A pre-fabricated sloped canopy of the same material of suitable dimensions to protect the cabinet from water and direct vertical sunlight shall be provided.

An air gap not less than 1.5 cm shall be present between the canopy and the cabinet.

Compartment Doors shall have robust weather-proof hinges of stainless steel with suitable lockable latching device. A metal pocket for the schematic diagram and the "as-built" diagram shall be provided in the enclosure door.

The door shall be designed in a manner that opening of 180 degree can be attained.

Enclosure shall be provided with a door switch-operated internal lamp fused circuit complete with 6 watt lamp suitably protected from accidental damage and located in the top side of the panel.

The panel shall have full size neutral and earth bar completely bonded to the main shell and connected to the door by a braided copper wire. Four numbers of openings in the bottom plate anchoring the feeder pillar to the concrete foundation shall be provided. A 3mm bakelite plate has to be included, separating the aluminum bottom from the concrete base. The controller housing panel shall allow building up equipment complying with IEC 439 and BS 5486-1.

Equipment Mounting Panel shall be hot dip galvanized steel sheet not less than 3 mm thick epoxy coated, and shall be easily installed and removed from the front of the cabinet in assembled form. All devices and equipment shall be accessible from the front of the panel. All hinges and locks are to be easily removable/replaceable.

Panel shall be provided with a removable gland plate near the bottom to fix compression type brass glands along with earth tag. All incoming and outgoing cables shall enter and leave the cabinet at the bottom.

Complete Pre-assembled Panel shall be appropriately packed and protected from damage during storage, shipment and handling. The feeder pillar dimensions shall be within the range specified on the Contractor's approved shop drawings.

Contactors: a contactor shall be provided to control simultaneously all outgoing circuits.

Contractors shall be of utilization category AC3.

Circuit Breakers: feeder pillars shall have moulded case circuit breakers for incoming and outgoing circuits. Refer to Section related to " L.V. Circuit Breakers".

Wiring and Cabling: internal wiring within the feeder pillars shall be with heat resisting, copper cables, arranged neatly and firmly attached. All the wiring leads shall be so arranged to allow current reading with a clip-on ammeter on each phase of main incoming and all outgoing circuits. All wiring shall be housed in wiring trunking forming an integral part of the enclosure whenever possible.

Busbars shall be of the same amperage ratings at 60 degrees C ambient at enclosure condition as the main circuit breaker and shall be made of tinned copper flats and round bars complying with BS 159, they shall be colour sleeved for easy phase identification and adequately supported to withstand dynamic stresses in the event of short circuit. Exposed busbars shall be insulated and screened to prevent accidental contact in live conditions. An earth or ground bar not less than 40 mm x 4 mm shall be solidly bolted with stainless steel bolts to the main body of the control cabinet.

All outgoing cables shall be connected through rugged terminals. All the connections must be done at the bottom. Lugs of suitable type and adequate capacity shall be used for cable terminals.

Each feeder pillar shall have one number 13 Amps single phase corrosion resistant switched socket outlet (3 pin square British type) as per BS 1363 or approved equal appropriately located and neatly and tightly fitted inside the enclosure.

All cable glands shall be brass compression type cable glands with earth tags and lock buds. All cable glands to be supplied with matching cables sleeves.

H.26.2.6 Control System

Photo Electric Switch: shall be submitted with related technical data sheets and certification for Engineer's Approval.

Time Switches: shall be submitted with related technical data sheets and certification for Engineer's Approval.

Selector Switch: a selector switch for performing the following functions shall be provided in the cabinet.

photocell and timer ON/OFF

timer ON photocell ON

H.26.3 Execution

H.26.3.1 Installation

Set units plumb, square, level, and secure according to manufacturer's written instructions and shop drawings.

H.26.3.2 Concrete Foundations

Column Bases: Install columns on concrete bases as detailed on the Contractor's approved shop drawings. Before commencement of construction, ensure that bases are suitable for column installation. Holding down and plumb adjusting nuts, washers, locknuts or nyloc nuts are to be stainless steel or cadmium plated

Construct concrete foundations with 3000-pound, 28-day concrete conforming to Section "Cast-In-Place Concrete." Comply with details and manufacturer's recommendations for reinforcing, anchor bolts, nuts, and washers.

Columns: erect columns so that luminaires are located on a line parallel to the theoretical profile of road. Alignment of columns, both horizontally and vertically, is to be secured to the satisfaction of the Engineer.

Embedded Poles: Set poles to indicated depth, but not less than 1/6 of pole length below finish grade. Dig holes large enough to permit the use of tampers the full depth of the hole. Backfill in 150 mm layers and thoroughly tamp each layer so compaction of backfill is equal to or greater than that of the undisturbed earth.

Fixture Attachment: Fasten to indicated structural supports.

Fixture Attachment with Adjustable Features or Aiming: Attach fixtures and supports to allow aiming for indicated / required light distribution.

Mounting Adjustment: after demonstrating to the Engineer that specified lighting requirements have been met, carry out final setting and locking in position of the floodlights.

Lamp fixtures with indicated lamps according to manufacturer's instructions. Replace malfunctioning lamps.

H.26.3.3 Grounding

Ground fixtures and metal poles according to Section "Grounding" and Bonding.

- Poles: Install 3.0 meter driven ground rod at the last pole of each circuit.

H.26.3.4 Field Quality Control

Inspect installed units for damage, quality of workmanship, alignment, perpendicularity, labeling and the like.

Provide advance notice of dates and times for field tests.

Provide instruments to make and record test results.

Tests: Verify normal operation of lighting units after installing fixtures and energizing circuits with normal power source. Include the following:

- Photometric Tests: Measure light intensities at locations where specific illumination performance is indicated. Use photometers with calibration referenced to NIST standards.
- Check for excessively noisy ballasts.
- Check for uniformity of illuminations.
- Insulation resistance and continuity tests.
- Written report of tests indicating actual illumination results.

Replace or repair damaged and malfunctioning units and retest.

H.26.3.5 Adjusting and Cleaning

Clean components on completion of installation. Use methods and materials recommended by manufacturer.

Adjust aimable fixtures to provide required light intensities.

H.27. STREET LIGHTING

H.27.1 General

H.27.1.1 Description

All goods and products covered by these specifications shall be submitted for Engineer's prior approval to confirm the compliance of these goods and products with the requirements set in these Specifications including, but without any limitation, the general requirements.

All materials and product shall be new and designed for operation in a corrosive atmosphere, extreme desert climate, and an ambient temperature of 50°C.

All materials and/or products shall be quality sampled and catalogues of products should be submitted to the Engineer, who will submit his recommendation to the Owner for final approval.

The Contractor shall be specifically responsible for the coordination and proper relation of his work to the site and shall visit the premises and thoroughly familiarize himself with all details of the work and working conditions. He shall verify all dimensions in the field and advise the Engineer of any discrepancy before performing any work to obtain written approval.

H.27.1.2 Applicable Codes and Standards

The following codes and standards are intended to provide an acceptable level of quality for materials and products. The Contractor may propose alternative code and standards providing they give an equivalent degree of quality as the referenced codes and standards and are submitted for Owner review and approval in advance of their use. All equipment furnished under these specifications shall conform to the appropriate standards of:

- Ministry of Industry and Electricity.
- NEC-National Electrical Code
- IEC: International Electrotechnical Commission
- IES-Illuminating Engineering Society
- ANSI-American National Standards Institute
- ASTM-American Society for Testing and Materials
- ASHREA / IESNA: American Society of Heating Refrigeration and Airconditioning Engineers 90.1 – 99.
- IECC: International Energy Conservation code, Code, 2000.

H.27.1.3 Submittals

The following shall be submitted to the Owner for approval prior to commencing work:

- A list identifying manufacturers and all material and equipment items proposed for use in the work of this Section.
- Manufacturer's Specifications, data sheets, shop drawings, installation instructions, operation instructions, and maintenance and repair recommendations for each item.
- Manufacturers' Certificates of Compliance: To indicate that each material and equipment item complies with the requirements of the specifications. Any test results shall also be submitted, in report form.
- As built drawings including complete details and comply with the actual excavated works at the site.

H.27.2 Products

H.27.2.1 General

All goods and products shall be new and designed for operation in a corrosive atmosphere at ambient temperature of 55°C and humidity of 20-80%.

H.27.2.2 Criteria for Lighting Pole Assemblies

These criteria apply to lighting pole and assemblies.

Poles shall be designed and fabricated for service under the following conditions:

- Wind Speed 140 km/hr.
- Temperature range 0°C to 55°C
- Relative humidity range 20% to 80%

All elements of lighting pole assemblies shall be designed and fabricated to preclude the entry of water.

H.27.2.3 Steel Poles

Poles

- Poles shall be tapered steel tubes fabricated from cold rolled steel conforming to specification ASTM A595 or A36. The pole shall be tapered uniformly for its full length. One longitudinal electric arc weld will be permitted. After welding, the pole shall be cold rolled to flatten the weld.
- Each pole shall be provided with a reinforced oval handhole. A removable steel handhole cover secured with stainless steel tamper proof screws shall be provided.
- Each hole shall be provided with a copper alloy grounding lug, readily accessible from the handhole.
- Steel poles and base plate shall be double hot-dip galvanized inside and outside.
- Steel poles in the landscaped area (3m height) shall be coloured as required by architect. (not applicable)
- The heights of different types of poles are shown on the Contractor's approved shop drawings.

Anchor Base

The anchor base shall be a one-piece steel casting conforming to the requirements of ASTM A 27, Grade 65-35. The base shall telescope the pole and shall be welded to the pole by two continuous electric arc welds. One weld shall be on the inside of the base at the butt end and the other weld shall be on the outside of the top of the base. The design shall be such that the welded connection will develop the full strength of the pole. Holding down bolts shall be ASTM A 325 Galvanized in accordance with ASTM A 153 .

H.27.2.4 Bollards (Not Applicable)

The bollard shaft shall be constructed of heavy gauge, thick wall aluminum in one seamless tube. The top cap shall be cast aluminum sealed against the weather and secured with a socket, tamper-proof screw. The internal cast aluminum base plate shall be secured with four (4) anchor bolts on a bolt-circle. The lamp holder shall be weather-proof ceramic designed for firm lamp support.

The bollard shall be provided with safety glass and anodized pure aluminum.

The all-aluminum construction architectural surface shall be finished with a nonlead black baked acrylic enamel or other selected finish.

The internal wiring shall be pre-installed at the place of assembly. The heights of bollard are shown on the Contractor's approved shop drawings.

H.27.2.5 Anchor Bolts

Anchor bolts shall be made from high strength steel having a minimum yield strength of 345 MPa. The threaded portion shall be 150mm long. Other dimensions shall be as shown on the Contractor's approved shop drawings. Two hexagon nuts and washers shall be furnished with each bolt; one for levelling and one for fastening. The threads of the bolts and the hexagon nuts shall be hot-dipped galvanized in accordance with ASTM A153.

H.27.2.6 Luminaires

General

Luminaires and all accessories shall comply with the requirements specified below: Voltage used shall be suitable for operation on 230V, 50 HZ. unless shown otherwise

in the Schedules and BOQ.

Only LED luminaire shall be considered.

H.27.2.7 Lighting Panel for Site

General:

- The Lighting Panel for Site shall be indoor and dust proof type.
- The design and construction of the panels shall take into consideration the safety of personnel under all operating conditions by the prevention of direct and indirect contact with live components under any operating, fault, and maintenance conditions. The general protection shall be achieved by means of enclosures which prevent any contact with the live parts. The spacing insulation level and mechanical strength shall be consistent with the stresses they may normally undergo. Also direct grounding of non-current carrying metal parts of panels through ground conductor to the ground bar is a very important protection against the danger that may occur when these parts become live.
- The housing shall be given a weather resistant outside finish consisting of a rust preventing primer and a finishing .

The distribution panel shall be complete with:

- An incoming moulded case Automatic Main Circuit Breaker: magnetic, thermal and earth leakage protection.
- 3 current transformers.
- Ammeters
- 1 three phase, four wire kW hour meter.
- 1 volt meter, scaled 0-500 volt with fuse and selector switch.
- 1 three pole contactor
- Thermal and magnetic 3 pole circuit breakers rated as shown on the Contractor's approved shop drawings to protect outgoing circuits.
- Main busbars. Three phases, one neutral, one earth.
- Secondary busbars.
- Wiring, control and labels.
- The circuit breakers shall be capable of withstanding a short circuit current in excess of 20000 amperes.

- The panel shall be separately earthed.

Control Equipment

- The control of street lighting shall be done through both a photo cell, timer and through Building Management system. Further manual override for all exterior lights shall be possible from the electrical panel for site lighting. The photo cell shall be mounted at the roof as shown on the Contractor's approved shop drawings with its circuitry. With the use of various relays, shall be integrated such that the photo cell shall switch on the lights while timer may switch at any time of the night as per the timings programmed on it. The control cables, for the control of street lighting shall be run in ducts being provided for telecom system.
- The contactors shall be NEMA type 1, enclosed, magnetic type, 500 volts, 50 hertz service, electrically held. The contractor shall be provided with a three positions "manual - Automatic - Off" switch.
- The contactors shall be installed inside the panel.

H.27.2.8 Cabling

Cable for feeders and branch circuits shall conform to NEC, and related Section requirements, with size, grade of insulation, voltage and manufacturer's name permanently marked on outer covering at regular intervals.

Cables shall be XLPE/SWA/PVC insulated, copper, stranded, with cross-sectional areas as shown on the Contractor's approved shop drawings. All conductors shall be made of high conductivity copper and shall be suitable for operation at 90°C conductor temperature without damage to associated insulation materials.

H.27.2.9 Ducts and Conduits

Ducts shall be polyvinyl chloride (PVC) and shall be provided in the types and sizes and at the locations indicated. Provisions shall be made for watertight connections at joints and for watertight caps or plugs at ends.

Bends shall be uniform throughout the arc of the bend and free from cross section deformations.

Longest single length shall be used to minimize the number of joints. Joints in short length runs embedded in concrete will not be permitted.

H.27.2.10 Grounding Materials

All metal non-current-carrying parts such as arms, accessories, enclosures and distribution cabinets shall be provided with separate ground wire with sized as per National Electrical Code.

Armouring shall be connected to the earthing lug/bar inside poles/panel respectively. Individual ground rods shall be installed as indicated in the Contractor's approved shop drawings.

Connections between dissimilar metals shall use appropriate compounds and be protected by painting over with a moisture resisting bituminous paint or by wrapping with a protective tape to exclude moisture.

Ground rods, connectors and other components of grounding assemblies, as shown in the Contractor's approved shop drawings, shall be those produced by a manufacturer regularly providing materials of the kind required. Components of like kind and size shall be identical throughout the work of this contract.

Grounding rods shall be straight, solid, undeformed copper-coated steel rods, in basic units 3.0 metres long and 16.0mm in diameter.

H.27.3 Execution

H.27.3.1 Installation of Street and Area Lighting Units

Before digging holes for erection of foundation the contractor shall proceed with the necessary topo-survey works for spotting the position of the columns according to the Contractor's approved shop drawings and the engineer's instructions.

After spotting the proper position of the columns and after approval by the engineer of the layout thus obtained, the contractor shall proceed with the digging of holes according to the dimensions shown on the Contractor's approved shop drawings.

Before erection of the columns, brackets (where provided) shall be fixed on the column according to the manufacturer's instructions. Columns shall be oriented so that their brackets be vertical to the axis of alignment or to the tangent of the curves.

The luminaires shall be carefully fixed on the brackets according to the manufacturer's instructions.

The Contractor shall make sure that they are mounted in the proper position in respect to the pavement of the road and the setting of the lamp holder and reflectors is according to the light distribution characteristics required.

Internal wiring and cable connections shall be made according to the Contractor's approved shop drawings and engineer's instruction. Special attention shall be paid when making cable connections so that the cable is not injured, cable terminals and wiring connections to the cable cores shall be wrapped with tape to avoid penetration of humidity.

Suitable miniature circuit breaker mounted in a terminating box, one for each lamp shall be provided in the gear compartment of the columns. Dimensions of this box shall be such as to permit its installation into the column gear compartment.

All wall mounted lighting fittings shall be fixed by approved methods and controlled directly from the lighting panel. The wiring system for lighting circuits shall be looped in with junction boxes as required. Junction boxes shall be mounted at uniform heights and shall match other equipment and be fixed with appropriate cover plates installed on the junction boxes.

All boxes concealed in walls shall have their edges flush with the surface of the wall.

H.27.3.2 Trenches and Cable Laying

Excavation of trenches is to be carried out.

- Along side walk
- Crossing road pavement
- On any other open area

Excavation of trench shall be carried out according to the Contractor's approved shop drawings and the engineer's instructions, the standing laws and by laws or instructions of the public or local authorities being applied.

If while excavating trenches electric power distribution cables, telephone cables, water supply piping, sewerage or rainwater piping, or public utility installations in general are found, the contractor shall inform the engineer accordingly and at the same time take all necessary precautionary measures to protect the aforementioned installations.

If a modification to the original layout of the trench and a change of its determined width and depth is deemed necessary this will be done only upon the engineer's instructions.

After the excavation of a trench and before laying of cables the contractor shall call the engineer to check dimension and run of the trenches.

Sand bed shall be furnished under the cables in trench, and covered by a layer of the sand and layer of concrete tiles, after that backfilling of trenches shall be effected by using the earth which was excavated.

Bending radius of the cable should not be less than that specified by the manufacturer.

Feeding will be done by using the looping cable (in and out) method.

The contractor shall take all necessary precautionary measures during the transportation and installation of the cables to prevent any mechanical strain or damage to them and he shall also see that the cable ends are completely insulated and protected against penetration of humidity.

H.27.3.3 Testing

The lighting system including all components shall be tested in an operational modes and to ensure that workmanship, materials employed and the method of installation conform to accepted construction procedures.

The Contractor shall furnish necessary meters, instruments, temporary wiring to perform the tests.

The Contractor shall submit to the engineer the testing program for approval, which covers all equipment provided.

The tests to be performed on the accomplished installations shall be at least:

- Illumination test
- Continuity test
- Insulation test
- Earth resistance test

Before circuit terminal connections are made, continuity and identification shall be checked by means of a DC test device using a bell or buzzer or battery powered phone to ringout wires. Both ends of a given conductor shall be identified alike. Polarity tests shall also be carried out.

Insulation test shall be applied in all cases between each phase and the earth and between each conductor against the others by using of a megger giving an output of 500 volt. During these insulation tests all the circuit breakers shall be off.

The insulation resistance shall be not less than 2 m. ohm. The insulation resistance, measured shall comply with the figures of a table, previously prepared by the contractor, and approved by the engineer, taking in the consideration the length of the circuits, the cross section of the cable and the ambient temperature of the tests.

Earthing resistance tests shall be done by using a suitable instrument, such as Whatson Bridge by connecting it to two testing rods, placed at 20 and 40m away from the instrument, and the earthing system. The measured electrical resistance shall not exceed 5 ohms.

Panel Test The tests applied to the panel are:

- Voltage and insulation test
- Mechanical performance test
- Checking the degree of protection against direct and indirect contact
- Functional tests.

H.28. SURGE PROTECTION SYSTEM

H.28.1 General

H.28.1.1 Summary

This section includes furnishing and installing a complete internal lightning protection system including lightning & over voltage arrestors. Class B Lightning arrestors shall be installed at the main distribution panels (DS, DP, PP) Class C over voltage arrestors shall be installed at the secondary distribution panel. (LP, MSP, PCP) Class D over voltage arrestors shall be installed as close as possible from the equipment to be protected (when necessary) as applicable.

System Design

The work covered under this section of the specifications consists of furnishing labor, materials and services required for the completion of a functional and inconspicuous lightning protection system approved by the architect and engineer. The design of this system is to be in strict accordance with this section of the specifications and all the Contractor's approved shop drawings that apply.

If any departure from the Contractor's approved shop drawings or submittal drawings covered below are deemed necessary by the Contractor, details of such departures and reasons therefore shall be submitted as soon as practical to the architect and engineer for approval.

The lightning protection work shall be coordinated with electrical earthing requirements and supplemental surge protection of electrical service(s), telephone service, antenna cables, etc.

Lightning protection design approaches such as "dissipation array" and "early streamer" systems are not acceptable.

H.28.1.2 References

Comply with the following applicable standards and codes:

- National Fire Protection Association (NFPA) a. NFPA 70 - National Electrical Code (NEC) b. NFPA 780 - Lightning Protection Code
- Underwriters Laboratories Inc. (UL) a. UL 96 - Standard for Lightning Protection Components b. UL 96A - Standard for Installation Requirements for Lightning Protection Systems c. UL 467 - Standard for Electrical Grounding and Bonding Equipment

Where differences arise between the specified standards and codes, the installation shall comply with the more rigorous and demanding requirements, whether or not shown on the Contractor's approved shop drawings. Similarly, comply with the more stringent requirements of this specification and drawings.

H.28.2 Products

H.28.2.1 Transient Overvoltage Protection for Main Power Distribution System

Transient overvoltage protectors should be installed on all power cables entering or leaving the building, in order to protect equipment connected to the power distribution system against transient overvoltages coming into the building from outside.

Protectors should also be installed at all power distribution boards in order to protect these against transients generated downstream of the previously mentioned protectors on incoming and outgoing power cables.

Protectors shall be tested in accordance with the requirements of BS 6651:1992, BS 2914:1972 and IEEE C62.41-1991.

The protectors must not interfere with or restrict the system's normal operation. They should not corrupt the normal main power supply, break or shutdown the power supply during operation, or have an excessive earth leakage current.

The protectors shall be rated for a peak discharge current of not less than 10KA (8/20microsecond waveform).

H.28.2.2 Class I (B) Arrestor

Lightning current arresters for main distribution switchboard or main distribution panel or main power panel (as applicable as PP or DP may in some cases be secondary panels depending on hierarchy of connection) should be of Class I (B) non-exhausting (encapsulated) with the following specifications:

- Class I (B) surge arrester
- $U_p < 2.5KV$
- $U_c = 255V$
- $I_{imp}: 50KA(10/350) / pole$
- $I_f = 50KArms$
- TOV Voltage = 335V for 5s
- Encapsulated
- Includes remote signaling possibility
- Includes operating voltage indication lamp
- Response time $< 100ns$
- Energy coordinated with Class II arresters without the use of inductance
- Serial & parallel connection possibility
- Includes possibility of arrester readiness remote signaling
- Part Number DEHN DBM255 L 900026
- Only class I (B) lightning current arresters with spark gap technology shall be accepted. Varistor based class I (B) SPD shall not be approved.

Class B Lightning current arresters shall be installed inside each main distribution panel(s) (MDB). TT installation configuration with N/PE arrester shall be used.

H.28.2.3 Class II (C) Over Voltage Arresters

Class II (C) arresters: To be installed at the power secondary distribution panel (PP, LP, PCP or MSP as applicable to the arrangement of power distribution) with the following specifications:

3 Stage protection: Green for Ready, Yellow for Module Exchange recommended, RED for Module damaged, replace immediately

$I_{max} = 65KA(8/20) / pole$

$I_n = 20KA (8/20)$

$U_c = 275V (AC), 350V (DC)$

Voltage protection level at I_n $U_p < 1.25KV$

TOV Voltage = 335V for 5s

Response time $< 25ns$

Max. mains-side overcurrent protection: 160A Gg/Gl

Short Circuit withstand capability at max. mains-side overcurrent protection = 20KArms

Includes possibility of arrester readiness remote signaling

Ready for installation in TT (TNS) installation without additional wiring

Part Number DEHN Dehnguard TT H230 LI 950150

Class II (C) overvoltage arresters shall be using MOV technology with thermodynamic disconnection in case of fault.

Class I (B) and Class II (C) arresters shall be installed according to manufacturer recommendation in order to provide energy coordination. Cable connections to arresters shall not allow 180 ° bends. When combined arresters are used, devices should comply to the following specifications: • Encapsulated, non-exhausting creepage discharge spark gap, with patented RADAX-Flow-Technology for the limitation and extinction of follow currents. • Energy-coordinated with surge arresters, Class C and D without additional Decoupling coils as well as directly with terminal units in Overvoltage Category I at $U_N = 230 \text{ V ac}$. • Low voltage protection level • Double terminals for all conductor connections as well as output multifunctional terminal for conductors and bus bars • Optional remote signalization • Integrated indication of voltage presence • Ready for TT or TNS installations

With the following technical specifications:

- Continuous Operating voltage 255V/50-60Hz
- Follow current extinguishing capability 50KA rms
- Lightning Impulse Current (10/350) 25/100KA
- Voltage protection level at $I_{imp} < 1.5 \text{ KV}$
- Response Time $< 100 \text{ ns}$
- back Up fuse 125A serial connection

315A parallel connection

- Short Circuit withstand capability at 50KA rms

max. backup fuse

- Enclosure material Thermoplastic UL94-V0
- Approved by KEMA, VDE

H.28.2.4 Class III (D) Arrester

Class III (D) arresters shall be installed next to the equipment to be protected with the following specifications:

(On branch breakers feeding all new power supply of central low current system panels)

- Continuous operating voltage 255V AC / 50Hz
- Tested to DIN VDE 0110 part 1
- Nominal discharge current 2.5KA (L(N)/PG), 5KA (L,N/PG)
- Voltage protection level $U_p < 1.5 \text{ KV}$
- Response time $< 100 \text{ ns (L(N)/PG)}$,
 $< 25 \text{ ns (L/N)}$
- Approved by UL or KEMA

Class III arresters shall have a visual functional indication (Green) and fault visual indication (Red) with possibility of remote signaling

H.28.3 Execution

H.28.3.1 Examination

Examine surfaces and conditions affecting performance of the lightning protection system. Do not proceed with installation until unsatisfactory conditions have been corrected.

H.28.3.2 Installation

Ordinary Structures:

- Install lightning protection systems, including modifications to existing systems, as indicated on the Contractor's approved shop drawings and according to manufacturer's written instructions, UL 96A, and NFPA 780 and other referenced codes and standards.

H.28.3.3 Verification

Verify that surfaces are ready to receive work.

Verify dimensions and measurements shown on shop drawings with field conditions.

Verify that all systems that may influence the lightning protection system design are included or referenced on the shop drawings.

Verify adequate guards against implement are in place or will be implemented as required by job progress.

Verify required procedures to prevent voiding of roofing warranty.

H.29. TESTING AND COMMISSIONING OF ELECTRICAL EQUIPMENT

H.29.1 General

H.29.1.1 Introduction

Scope

- This specification outlines the minimum inspection and electrical acceptance tests required before start-up of electrical equipment, wire, cable and apparatus.
- It is intended that this specification be used, as guide and it shall not be construed as deleting other tests specifically outlined in other sections of the specifications.

General Requirements

- Access shall be afforded at all the times to the Engineer to enable him to inspect the Electrical Equipment.
- Upon completion of the Electrical Equipment installation or part of the installation, the contractor shall carry out and be responsible for testing and commissioning it, in stages if required, to ensure that it is in proper working order and capable of performing all of its functions in accordance with the specification and to the satisfaction of

the engineer. Any Electrical Equipment damaged in commissioning shall be replaced and retested by the Contractor at his own expense to the satisfaction of the engineer.

- All testing shall be carried out according to the requirements of the relevant standards and regulations as may be stated or implied in the specification or otherwise agreed by the Engineer in writing.
- The contractor shall submit, in no later than 6 weeks prior to the commencement of testing and commissioning, a schedule of all Electrical Equipment tests and commissioning procedures that he intends to carry out to prove that the Electrical Equipment complies with the requirements of the Specification together with his proposed programme for such tests and commissioning.
- Tests shall not commence before the schedule of tests has been approved and such other tests as may be required by the Engineer shall be included within the schedule of tests.
- The contractor shall give to the engineer in writing at least ten days' notice of the date by which he will be ready to make the specified tests on completion of installation. Unless otherwise agreed the tests shall take place within seven days after the said date on such day or days as the engineer shall extend in writing notify the contractor.
- The tests shall as far as possible be carried out under normal working conditions to the satisfaction of the engineer and shall extend over such periods as he may direct.
- The contractor shall provide all skilled labour, supervision, apparatus and instruments required for commissioning and testing and within a reasonable time thereafter furnish to the engineer a total of six certificates of all tests performed and accepted, signed by the contractor, or an authorized person acting on his behalf, as prescribed in the appropriate regulations and specifications.
- If any part of the Electrical Equipment fails to pass the specified tests, further tests shall, if required by the Engineer, be repeated. The contractor shall, without delay, put in hand such modifications as are necessary to meet the requirements as described in the contract and any expense which the Client may have incurred by reason of such further tests may be deducted from the contract price.
- Acceptance shall not in any way absolve the contractor of his responsibility for the performance of the electrical Equipment after erection as a complete working system in all respects.
- Each completed system within the installation shall be tested as whole under normal site operating conditions to ensure that each component functions correctly in conjunction with the rest of the system.

H.29.2 Testing

H.29.2.1 Testing Requirements

All tests shall be carried out in presence of the Engineer.

Notwithstanding the above, the testing requirement shall be endorsed by the specific requirements set out in the Specification for specialist installations, and to the particular performance standards therein.

The following tests shall be carried out, as appropriate or when required by the Engineer.

Where modifications and alternations on existing systems and installations are to be undertaken then the contractor shall carry out all necessary tests to establish the integrity of such systems and installations before any modifications and alternations are commenced and again when such modifications and alterations are completed.

H.29.2.2 Electrical Testing

At the completion of the electrical installation for each facility it shall be tested to ensure that it is satisfactory and complies with the requirements of the specification.

Tests of the installations shall be carried out in the following sequence:

- Ring-main continuity.
- Protective conductor continuity, including main and supplementary equipotential bonding.
- Earth electrode resistance.
- Measurement of insulations resistance including site built assemblies and distribution.
- Check of protection by electrical separation, barriers and enclosures.
- Measurement of the insulation on non-conducting floors and walls.
- Check of phase rotation.
- Verification of polarity.
- Measurement of earth fault loop impedance.
- Test of operation of residual current devices.

H.29.2.3 Testing Phases and Sequence

All the electrical systems and equipment shall undergo following phases of testing and commissioning, in accordance with the actual site requirements and as approved by the Engineer:

- Phase 1 : Works testing and quality assurance of elements.
- Phase 2 : Site installation, wiring, checks, performance and operational tests for all elements.
- Phase 3 : Sub system group operational tests/performance tests.
- Phase 4 : Complete system operational and performance tests on Dummy loads.
- Phase 5 : Complete system operational and performance tests on actual loads.

Testing of all the electrical installations shall be carried out in the following sequence as applicable and approved by the Engineer:

- Ring-main continuity.
- Protective conductor continuity, including main and supplementary equipotential bonding.
- Earth electrode resistance.
- Measurement of insulation resistance including site built assemblies and distribution cables.
- Check of protection by electrical separation, barriers and enclosures.
- Measurement of the insulation on non-conducting floors and walls.
- Check of phase rotation.
- Verification of polarity.
- Measurement of earth fault loop impedance.
- Test of operation of residual current devices.
- All external distribution cables, both medium and low voltage in accordance with the relevant standard(s).

- Fault simulation on protective devices or control systems of stand-by generators, transformers, 3.3 kV cubicles, power distribution boards, motor control centers, etc., as applicable. Load test on sub-station, power distribution boards, panelboards, etc., as applicable.
- All 3.3 kV cables and equipment shall be pressure tested. Submit a method statement for the test procedure, voltage levels and safety precautions.
- Complete testing of lighting control system.
- Complete testing of central battery system.

H.29.2.4 Earth Resistance Testing

Carry out earth resistance tests after installation of the individual Earthing Systems in accordance with the IEE Wiring Regulation 16th edition.

Prior to connection of earth rods to the Earthing System, measure the earth resistance of individual earth rod by using an approved type of earth resistance tester.

After completion of all the connections of Earthing System, measure the earth resistance from the earthing, test point in presence of the Engineer.

Record all the readings obtained, duly witnessed by all parties and submit the earth resistance test reports for Engineer's approval.

Similarly carry out earth resistance tests after installation of the Lightning Protection System in accordance with IEE Wiring Regulations, 16th edition and BS 6651.

H.29.2.5 Miscellaneous Testing

All tests listed under the heading of "Field Quality Control" and anywhere else in the miscellaneous sections of these Specifications shall be conducted in the presence of and performed up to the full satisfaction of the Engineer. All the results/test reports shall be submitted in bound form for Engineer's approval.

Carry out electrical testing of all the electric-operated equipment provided under other Sections of the Specifications such as elevators, trash compactors, motorized doors / blinds, arm barriers, water features, swimming pool, etc. in accordance with the applicable

Develop and submit for Engineer's approval prior to implementation, a safety tagging procedure for use when working on energized systems or to identify systems that have been turned over to operations.

Provide plastic tags of minimum dimensions 300 x 200 x 3 mm with appropriate internationally recognized pictorial symbols and statements in Arabic and English languages for use as safety tag. The tags shall be colored red with white letters or colored yellow with black letters as approved by the Engineer. The letters shall be at least 20 mm high or more as required. The safety tag shall be provided with fire resistant rope for suspension at suitable locations.

Type of safety tags shall include, but not limited to, the following:

- Refer to the equipment instructions/manual for important information before proceeding.
- This unit must be accessed only by qualified personnel.
- Do not switch ON. Work is in progress on other end.
- Danger - Hazardous AC (or DC) voltage.
- Danger - AC mains voltage.
- Danger - Hot surface. Do not touch without taking care.

- Risk of injury due to high current.
- Avoid contacting conductors with un-insulated metal objects. Follow safety precautions. Make sure the power is disconnected.
- Danger - Arcing/Sparking may happen. Risk of eye injury. Always wear safety glasses.
- Make sure the equipment is grounded before switching ON power.

The installation and removal of safety tagging shall be carried out with the permission of an authorized Client's or Engineer's representative.

Approved type of pad locks shall be provided to lock out any circuit breaker, isolator, switch fuse or a piece of equipment to prevent accidental turn ON or turn OFF. The keys shall be in the custody of an authorized Client's or Engineer's representative.

H.29.3 Commissioning

H.29.3.1 General

All Electrical Equipment and integral systems shall be commissioned in accordance with the relevant standards and regulations given in the specification and to the recommendations of specialist suppliers (e.g. switchboard, Standby Generators, Fire Protection and Alarm Systems, and Public Address Systems, Cables, etc.)

Full operational tests shall be carried out on all systems to demonstrate that they operate in accordance with the requirements of the Specification.

H.29.3.2 Switchboards

Design tests of: Rated continuous current short circuit current enclosure

Production tests of: Dielectric Mechanical Operation

Grounding Control

Wiring Electrical

Operation.

H.29.3.3 Standby Generator

Field erected fuel piping shall be tested with air pressure and proven right at 150 percent of the working pressure for a period of two hours.

Shops tests shall be performed in accordance with the following requirements:

- Unless otherwise directed, all tests shall be performed in the presence of Supervising Engineer.
- Each assembled engine and generator shall be tested in accordance with the manufacturer's customary practice.
- All components shall be checked. Lube-oil leaks shall be remedied.

Following the complete installation of the generating unit and its associated equipment, field tests shall be conducted. The Contractor shall provide all instruments and supplies required for the tests. Fuel instruments and instrumentation procedure to be followed shall be appropriate for the tests to be performed. Prior to the startup of any generating units, the Contractor shall demonstrate to the satisfaction of the contracting officer that all piping systems have been cleaned.

Sequence of Field Tests:

- Check all engine and driven unit mounting bolts.

- Check alignment of engine and generator by dial indication.
- Check generator motor air gap.
- Check generator and exciter insulation resistance with an insulation resistance tester.
- Perform engine manufacturer's recommended prestarting checks. This shall include a test of the prestart lube -oil pump to determine if adequate oil pressure is provided.
- Start engine and make engine manufacturer's after starting checks during a reasonable run -in or warm-up period.
- Operate generator with step loads of 25%, 40% & 75% with 100% for 7 hours and 110% for 1 hour rated load. Record data hourly, including current, voltage, frequency KW and temperature information. A load bank has to be provided by the Contractor.
- Increase engine speed by means of the governor. Check speed at which over speed device trips.
- Check functioning of high coolant temperature trip by restricting air into the radiator.
- Shut down engine and record pressure at which low oil pressure device trips.

Checks to be made during field testing:

- During the tests, all operations of which the controls on the panels and at the switchboard are capable shall be performed to assure that all controls are functioning in a satisfactory manner.
- At several points during the tests, each instrument on the switchboard and engine panel shall be observed to assure that all instruments and gauges are functioning properly.
- During the tests, all auxiliary and accessory equipment, all valves including pilot valves, and the injection pumps shall be checked to assure proper operation.
- During the 100 percent load test, pyrometer reading of each cylinder of each engine shall be taken and recorded at ½ hour intervals.

Inspection of Field Testing

- After completion of the tests, a general inspection shall be made for: a. Leaks in the engine, piping systems, tanks etc. b. Blow-by.

c. Crankcase Contamination.

d. Crankshaft misalignment. e. Generator misalignment and damage to generator bearings.

H.29.3.4 Automatic Transfer Switches

Automatic Transfer Switches shall be given to the following visual and mechanical inspections.

- Inspect for physical damage. Compare equipment nameplate information and connections with the single line diagram.
- Check switch to insure positive interlock between normal and alternate sources.
- Check tightness of all cable connections and bus joints.
- Perform manual transfer operation.

Automatic Transfer Switches shall be subjected to the following electrical tests.

- Perform insulation resistance tests from phase to phase and from phase to ground with switch in both source positions. The tests voltage levels and minimum acceptable test results shall be approved by the Engineer.
- Set and calibrate the following in accordance with the specifications, as applicable. a. Voltage sensing relays. b. Transfer time delay relay .

- Perform an automatic transfer operation by the following: a. Simulating a loss of power. b. Return to normal power.
- Monitor and verify the correct operation and timing of the following, as applicable: a. Normal voltage sensing relays. b. Time delay upon transfer. c. Alternate voltage sensing relays. d. Automatic transfer operation. e. Interlocks and limit switch function. f. Timing delay and retransfer upon normal restore action.

All component devices shall be inspected and tested as required by the applicable sections of this specification.

H.29.3.5 Motor Control Centers

Motor Control Centers shall be given the following visual and mechanical inspections.

- Inspect for physical damage. Compare equipment nameplate information and connections with the single line diagram. A visual check of all starter locations, nameplates, etc. shall be made against design plans. Check for proper anchorage and grounding.
- Compare overload heaters with motor full load current for proper size.
- Check tightness of bolted connection.
- Check ratings of and make settings on all over-current protective devices.
- Check phasing of buses. All buses shall be phased so that circuit breaker phase identification is 1-2-3, left to right as viewed from the front of the breaker. Phase identifications 1-2-3 are equivalent to transformer to phase identification x1-x2- x3 and phase identification A-B-C as viewed from the front of the equipment.

Motor Control Centers shall be subjected to the following electrical tests.

- The following insulation tests shall be performed. Before testing the equipment ground bus shall pass all tests. a. Measure the insulation resistance of each bus section from phase to phase and from phase to ground for one (1) minute with a 1000 V megger. The minimum acceptable resistance shall be thirty (30) megohms. b. Measure the insulation resistance of each starter section from phase to phase and from phase to ground with the starter contacts closed and the protective device open for one (1) minute with 1000 V megger. The

minimum acceptable resistance shall be thirty (30) Megohms. c. Measure the insulation resistance of each control circuit with respect to ground with a 500 V megger. The manufacturer shall be consulted for test voltage where solid state control devices are utilized. The minimum acceptable resistance shall be two (2) megohms.

- A functional check of all wiring shall be made against applicable interconnection wiring diagrams.
- With control circuits properly energized check operation of all controls and inter-locks.
- Mechanical and electrical operational tests shall be performed on all breakers and their starters and associated alarm and indicating devices.
- All component devices shall be inspected and tested as required by the applicable sections of this specification.

H.29.4 Instruction and Training

H.29.4.1 Instruction and Training of Client Staff

The Contractor shall be responsible for the provision of suitably qualified personnel for the instruction and supervision of the staff nominated by the Client at Site in the operation and routine maintenance of all Electrical Equipment and associated works. The instruction and training shall be for periods of six hours daily for twelve days after satisfactory commissioning of the installation and as necessary, after each subsequent commissioning of a system or part thereof.

The Contractor shall accept for training up to four technicians in every system nominated by the Client who will be assigned to train in all aspects of the installation on site during operation of the installation.

The cost of the training will be the contractor's responsibility. During the training period the salaries of the trainees, their subsistence and all their out of pocket expenses will be the responsibility of the Client.

Before the commencement of such training, the contractor shall have available additional copies of sufficient As Built drawings record drawings, operating and maintenance instructions and spare parts lists, so that the staff nominated can fully understand the operation and maintenance of the equipment. Two months prior to the commencement of commissioning and training, the Contractor shall submit to the Engineer of the commissioning, regulation and testing, together with training program.

H.30. MEDIUM VOLTAGE CABLES AND ACCESSORIES

H.30.1 General

H.30.1.1 Sections Includes

MV Cables and Accessories rated 20 KV including, but not be limited to, the following:

- Multi core MV cables.
- Earth cable.
- Splices and terminations.
- Cable markers, support and ties.

H.30.1.2 References

- NFPA 70 National Electrical Code (NEC)
- IEC 223 Conductors for Insulated Cables.
- IEC 502 Extruded Solid Dielectric Insulated Cables for Rated Voltages from 1 kV up to 30kV.
- IPCEA S61-402 Thermoplastic Insulated Cable and Wire, 0 to 35 KV(NEMA WC5)

H.30.1.3 Submittals

Submit samples of each type of cable proposed.

For all types and sizes of cables, submit the following Manufacturer's details:

- Dimensions
- Weight
- Construction
- Current rating
- Manner of installation
- Maximum conductor operating temperature
- Volt drop / amp / meter
- Impedance: Separate resistance and reactance values of single and multi-core cables
- Characteristic curves for short circuit rating
- Minimum bending radius

Submit factory/shop test results showing test voltages, duration of tests and polarization indices for each routine test, in accordance with the requirements of IEC Standards. Submit the results of type tests when required by the Engineer.

Submit cable termination diagrams and jointing details.

H.30.1.4 Quality Assurance

Manufacturers: Firms regularly engaged in manufacture of MV cables and accessories of the types, sizes and ratings required, whose products have been in satisfactory use in similar service for not less than 15 years.

Installer: Firms regularly engaged and qualified with at least 5 years of successful installation experience on projects with electrical installation work similar to that required for the project.

Cables shall generally be Manufacturer's standard construction and materials. Where this contradicts any part of the Specifications, the Contractor shall state so, at the time of tender.

All MV cables and accessories furnished under these Specifications shall conform to applicable standards of the Electricity Supply Authority, IEC, NEC.

H.30.1.5 Delivery, Storage and Handling

End of cables shall be sealed to prevent ingress of moisture.

All cables shall be transported on drums with solid timber battens for protection of cables over the circumferences of the drums. Drums shall not be transported on their sides. Each cable drum shall be provided with appropriate weatherproof metallic label indicating project name, order no., type, size and length of the cable delivered.

Care shall be taken during transit to avoid damage to cable and drums. Before acceptance on site, cable drums and cables shall be inspected for:

- Damage.
- Compliance with Specifications.
- Quantity.

All MV Cables and accessories shall be stored in factory installed coverings in a clean, dry indoor space which provides protection against the weather and direct exposure to the sun light.

As far as possible, each distribution cable shall be supplied in one continuous length without any joint. Where the required run length of any individual cable exceeds the maximum/standard length of a cable drum, as Manufactured in the factory, the cables shall be jointed with prior approval of the Engineer using an approved cable joint.

Cables shall be handled with care and every effort made to avoid damage to the cable, to other services and to building fabric. Recommendations or instructions available from the cable manufacturers concerning the installation of cables shall be taken into account. Any damage shall be reported immediately to the Engineer.

Cable drums shall be unloaded carefully by means of either a crane or ramp and impact with the ground shall be avoided. They shall be supported on axles and axle stands while the cable is being pulled; twisting and abrasion of the cable serving or over-sheath shall be avoided.

H.30.2 Products

H.30.2.1 General

A 15kV circuit as referred to herein or shown elsewhere in the Contract Documents shall comprise three single cores and / or one three-core cable rated 20kV armoured as shown on the Contractor's approved shop drawings for the 5.5 Kv circuit the cable shall be rated 6 Kv.

H.30.2.2 Single Core MV Cables

Provide single core or 3 core, armored MV cable rated, as shown on the Contractor's approved shop drawings. The cables shall conform to the following minimum requirements:

- Conductor: Concentric circular copper, stranded to IEC 60228 class 2.
- Conductor Screen: Extruded semi-conducting thermosetting material, 0.3 mm minimum thickness.
- Insulation: Cross-linked thermosetting polyethylene (XLPE), rated 90 °C to IEC 60502-2 and containing no carbon black. Manufacturer shall warranty that the insulation will not emit any toxic fumes in the event of a fire.
- Insulation Shield: Extruded semi-conducting thermosetting material and Uncoated copper tape. Metal shield shall have a fault capability of 1,000 Amps rms symmetrical minimum for 1 second. Semi-conducting material shield shall be readily removable for termination.
- Armour: Two layer of steel tape conforming to the applicable requirement of IEC 60502-2.
- Jacket: Red over-sheath of Low Smoke Fume material (LSF) as approved. Manufacturer shall warranty that the jacket will not emit any toxic fumes in the event of a fire.
- Making: A durable marking shall be provided on the surface of the outer jacket (over-sheath) at intervals not exceeding 610 mm. Marking shall include Manufacturer's name, insulating material, conductor size and voltage class. Cores shall be marked by red, yellow and blue tapes applied within the insulation screen.
- Outside Diameter: As per IEC 60502-2.

Coordinate the critical dimensions of the cable to be within the allowable tolerances of the pre-molded splices and tapes. Cables which do not allow utilization of pre-molded splices and tapes shall be removed from the work site.

The short circuit ratings of all MV cables shall be coordinated with associated MV switchgear and short circuit study / calculations.

H.30.2.3 Splices and Terminations

Cable splicing or jointing shall not be allowed in any circumstances, except where the required run length of any individual cable exceeds the maximum / standard length as Manufactured in the factory. Obtain Engineer's written approval for any splice or joint, prior to ordering the cable.

Splices and terminations for all MV Cables shall be furnished in kit form and shall conform to the recommendations of the cable Manufacturer. All material shall be furnished in factory sealed packages and shall not be opened until required for use.

Splices for all MV Cables shall be pre-molded and rated for continuous duty at the rating of the services to which they are connected and 21,000 asymmetrical amps momentary. They shall be suitable for direct buried underground installation or mounted on cable trays as per the requirements on site.

Termination shall be insulated using the materials specified and the procedures recommended by the Manufacturer of the kit being used.

Splices for the earth shall be made exothermally or as per the recommendations of MV cable splice Manufacturer.

H.30.2.4 Cable Markers, Supports and Ties

Cable markers and identification discs for all MV Cables shall be provided.

H.30.2.5 Earth Cable

Provide separate earth cable in all medium voltage ring and radial circuits in accordance with applicable International Standards and requirements.

The size of earth cable for each MV cables or circuit shall be based upon short circuit calculations, but in any case not less than 95mm².

H.30.3 Execution

H.30.3.1 Inspection

Examine the areas and conditions under which the cables are to be installed and correct any unsatisfactory conditions detrimental to the proper and timely completion of the work. Do not proceed with the work until all unsatisfactory conditions have been corrected in a manner acceptable to the Engineer.

H.30.3.2 Cable Installation

No work shall commence until the Contractor has investigated the site satisfactorily, and ascertained that the area is free from drains or other underground services. The Contractor shall obtain approval of the routes for external cables with appropriate installation details on shop drawings prior to commencement of any excavation on site.

Pull cables off drum mounted on cable jacks or a stationary cable trailer. Care shall be taken to protect the cable at all times during the installation process. Cable rollers shall be used to prevent undue friction below the cable and at all changes in direction. The Contractor shall comply with all other Manufacturer's instructions.

Pull cables into position using a conductor pull or a wire basket over the metallic insulation screen.

When installing into a duct system via a manhole, utilize a feeding tube long enough to reach from the conduit entrance to the outside of the manhole.

When installing into cable ducts, all cables shall be installed singly and continuous between the manholes. Splicing of cables between the manholes shall not be allowed in any case.

For cables pulled into thrust boring or cable ducts exceeding 10 m length, use cable stockings for hauling. Precautions shall be taken to ensure that strain is taken on the cable cores as well as on the sheath. The pulling tension of the cable shall not exceed the maximum tension recommended by the Cable Manufacturer.

Utilize both manual and power types pulling mechanisms on site as required with the rated capacity (in Newtons) clearly marked on the mechanism. A dynamometer shall be used to show the tension on the cable during all pulls and the indicator shall be constantly watched. If any excessive strain develops, the pulling operation shall be stopped at once and the difficulty determined and corrected. The dynamometer shall have a maximum tension indicator to show the maximum tension developed during a pull. The cable play-out reel shall be equipped with a suitable brake and shall be constantly manned during all pulls.

Under no circumstances cable shall be pulled using equipment not monitored by a dynamometer. The use of motor vehicles in pulling cable is prohibited.

Installation:

- Only personnel qualified and experienced in this type of work shall make connections.
- Cables shall be installed with care to avoid damage. 1. Cables showing damage after installation shall be replaced. 2. Rollers and spools shall be used in adequate numbers for pulling in cables. 3. Lubrication shall be as approved for the insulation and raceway material. 4. Prior to pulling, calculations of pulling tension and sidewall pressure shall be submitted. 5. A dynamometer shall be used and tension shall be recorded for all MV pulls.

Cable installation details:

- Cable pulling tension shall not exceed the smallest of following values: 1. Allowable tension on conductor as published by the manufacturer. 2. Allowable tension on pulling devices. 3. Allowable sidewall tension.
- Cable-pulling attachment must be to the conductor only, and devices should be staggered to prevent over tensioning of pulling device.
- Cable continuity and phase identification shall be checked and tagged, using 2.5cm by 7.5cm plastic tags. In manholes, cables shall be identified and have tags installed where cables enter and leave the manhole. Phase positions at terminating equipment shall be Phase A-B-C left to right facing the front, or A-B-C front to back, A-B-C top to bottom. Phasing must be confirmed before placing cable system into operation.
- Flame-proofing: Cables in manholes, vaults, etc., shall be flame-proofed with pressure-sensitive applied flame-proof tape.

To avoid insulation damage from excessive side wall pressure at bends in raceway runs, the pulling tension in the cable in Kg as it leaves the bend shall not exceed 500 times the radius of the bend in meters.

Support cables at all times without excessive sag. Cables shall be located in such a way as to minimize interference with other cables to be installed.

Provide adequate length of cables in manholes to avoid distorting pressures on the cables at conduit bushings. Provide cable protection such as a layer of light rubber belting, friction tape or similar material where required before permanently fixing the cables in place.

Exercise extreme care to prevent tension during bending of MV Cables. The permanent radius of cable bend at any location after installation shall not be lesser than the cable Manufacturer's recommendations.

Seal cable ends during pulling and immediately after cutting if splices or terminations are not to be made immediately.

Arc proof for all MV cables in manholes and building entrances. Arc proofing in a manhole shall be extended in one helically wound half lapped layer from one duct end along the cable to the other duct end. Secure arc proofing in position with glass tape randomly wrapped to the instructions of the arc proofing tape Manufacturer.

Shields and armour of MV cables shall be earthed at both ends.

Install cable markers and identification discs in accordance with the requirements and locate them so that they are readily visible when cable is permanently fixed in position.

Follow installation requirements and procedures of Local Electricity Authority and provide all accessories to comply with their procedures for power connection requirements.

H.30.3.3 Splicing and Terminations

Cable joints and termination:

- Cable joints and termination must be of the same rating as conductors. Provide fully shielded joints for each phase conductor.

- In underground structures (e.g, manholes), provide watertight, fully submersible joints and terminations. Under no circumstance shall cable joints be installed in raceways.

Splicing and terminations of all MV cables shall be carried out by the personnel certified by Local Electricity Authority or the Owner.

Utilize appropriate crimping tools for splicing and terminations of all MV Cables, with guides to position the connectors or lugs in the tool correctly. The connectors, lugs and associated dies shall be of correct type and size suitable for the MV cable under splicing or terminations. Crimping tools shall be designed with steps to prevent over- crimping and shall be of a type which has provision to prevent the tool from opening until the crimp action is completed. Crimping tools shall be a product of the connector Manufacturer.

Comply with Manufacturer's recommendations and instructions for splicing and terminations of MV cables, provided these do not contradict the applicable standards.

Splices shall not be made to utilize short lengths of cable. When cables are being installed into a duct system with manholes, the splices shall only be provided within the manholes and no splice shall be allowed outside the manholes.

Keep work areas dry, dust free and ventilated during splicing and terminating MV cables.

Before making final splice or termination of MV cables, ensure conductor phasing is correct.

Where the shape and configuration of terminal fittings make workmanlike insulation of the bare connection impractical, the contours of the connection shall be smoothed by filling voids and moulding over irregular surface with electrical putty before application of the recommended thickness of insulating material.

Medium-voltage cable terminations:

- Phase-mark each conductor, secure conductors adequately, and observe cable bend radius limitations. Construction Management will identify the phase rotation convention.
- System phase sequence is A-B-C.
- Medium – voltage switch phase terminations shall be A-B-C left to right when facing the front of the switch.
- Junction box phase terminations are A-B-C left to right.
- Standard link box phase terminations are A-B-C left to right, top to bottom, front to back. Some existing link box phase terminations are not standard, especially on the normal and emergency power system.
- Install cable terminations per manufacturer's recommendations.
- Medium-voltage cable splices shall be made only when absolutely necessary. When necessary, splices shall be made only by personnel qualified and experienced in this type of work.
- All terminations shall be secure and tightened in accordance with the manufacturer's recommendations.

H.30.3.4 Field Quality Control

All MV cables shall be tested when splicing and terminations are fully prepared and completed except for final connections of cable tails onto equipment.

Test each conductor for phasing, continuity and insulation resistance.

After completion of the installation of all MV cables, carry out a high voltage DC insulation test between each conductor and earth at 214 times the phase to earth working voltage for 15 minutes. Full tests shall be carried out only once. Where preliminary tests are required on sections of cable prior to terminating or jointing they shall be carried out at reduced time and voltage. Test procedures shall be in accordance with the appropriate IEC standard.

Testing of medium-voltage terminations:

- Cable continuity and phase identification must be checked. Cables shall not be subjected to more than one high potential test without approval of the Engineer.
- The DC potential test voltage to be applied shall be 80 percent of manufacturer's acceptance test voltage level, applied in increment steps until the 80 percent value is reached; then the 80 percent value must be held for 15 minutes. The test voltage should be applied gradually during the first minutes, with initial application being not greater than the rated voltage of the cable.
- During high potential test, leakage current readings shall be taken at 30-second intervals during the first 2 minutes of the test and at 1-minute intervals during the remainder of the test. If after the first minutes the leakage current increases, the Engineer may elect to stop the test. No test will be accepted while there is continual increase in leakage current throughout the test. The cable must withstand the specified high-voltage test without breakdown.
- Test record shall include the following: 1. Complete identification of cable, including approximate length. 2. High potential value, leakage current value, and time data. 3. The approximate average cable temperature and humidity. 4. High potential versus leakage current plot.

In addition to above, carry out any test(s) required to comply with the procedures of Local Electricity Authority for power connection requirements.

H.31. MV (5.5 KV) SWITCHGEAR (METAL ENCLOSED)

H.31.1 General

H.31.1.1 Section Includes

Medium Voltage (5.5 KV) switchgear and associated equipment including, but not limited to, the following:

- MV (5.5 kV) metal enclosed switchgear.
- DC battery and charger.
- Cable glands.
- Accessories.

H.31.1.2 Related Sections

- Submittals.
- Materials and Equipment.
- Starting of Systems.
- Basic Electrical Requirements.
- MV Cables and Accessories.
- Testing and Commissioning.

H.31.1.3 References

- IEC 60298 AC Metal enclosed Switchgear and Control gear for Rated Voltages above 1 kV.
- IEC 60056 High Voltage Alternating Current Circuit Breakers.
- IEC 60185 Current Transformer.
- IEC 60186 Voltage Transformer.

- IEC 60255 Electrical Relays.
- IEC 60529 Degrees of Protection of Enclosures.

H.31.1.4 Quality Assurance

MV switchgear(s) shall only be purchased from firms regularly engaged in manufacture of MV switchgears of types and ratings required, whose products have been in satisfactory use in similar service for not less than 15 years.

Installer shall be qualified with at least 10 years of successful installation experience on projects with electrical installation work similar to that required for the project.

All MV (5.5 kV) equipment shall be from the same manufacturer, comply with the requirements of IEC, NEC and Electricity Supply Authority.

H.31.1.5 Submittals

Submit manufacturer's catalogues and data including shop and schematic drawings, dimensioned layout of equipment and accessories, technical specifications, installation instruction and general recommendations. Include data substantiating that the proposed units comply with the project requirements.

Submit list of tools, test equipment, spare parts and ancillary equipment.

The supplier shall submit the factory test reports verifying that the MV switchgear has successfully passed all routine tests. Type tests results shall be submitted, if required by the supervising Engineer.

H.31.1.6 Delivery, Storage and Handling

Deliver, store, protect, and handle products in accordance with recommended practices listed in manufacturer's installation and Maintenance manuals.

Deliver each medium voltage metal clad switchgear section in individual shipping splits for ease of handling. Each Section shall be mounted on shipping skids and wrapped for protection.

Handle the packaged cubicles carefully to prevent breakage, denting or scoring the finish. Store equipment at an indoor location and protect from weather. When outdoor storage is necessary, elevate well above ground and enclose with durable, waterproof wrapping and protect from direct sun.

H.31.1.7 Warranty

Manufacturer warrants equipment to be free from defects in materials and workmanship for 1 year from date of installation or 18 months from date of purchase, whichever occurs first.

H.31.2 Products

H.31.2.1 General

All material is used in the manufacture and installation of MV switchgear shall be of high quality and of proven suitability for the functions they will perform and the conditions they will meet in service.

Rating shall be as indicated on corresponding Drawings.

H.31.2.2 MV Switchgear

The MV switchgear shall be constructed based on following system parameters:

- Voltage : 5.5 KV, 3 phase.

- Frequency : 50Hz
- Basic Impulse Level (BIL) : 60kV
- Symmetrical Fault Level : 63kA RMS (1 second)
- Neutral : Resistance earthed.

Rated peak withstand current shall not be less than 2.5 times the system short circuit level.

MV switchgear design shall be as follows:

- The MV switchgear shall be metal enclosed single bus bar, indoor, with draw able type of modular design, with all modules standardized and interchangeable. The finishing color shall be light admiralty grey..
- When found necessary by the Engineer, provide 2 compartments for the Bus Section Switch.
- The design shall ensure all round protection against contact with live parts even with the circuit breaker truck withdrawn.
- The MV switchgear shall afford full protection for personnel and include any arc resistant front plate with a safe and positive interlocking system.
- The MV switchgear metal enclosed "compartments shall be constructed to IP 41 protection level to ensure that collection of dust is reduced to a minimum and the intrusion of vermin is prevented.
- Circuit breakers shall be SF 6 type with hand and motor charged spring operated mechanism. Circuit breakers of the same type and current rating shall be wired alike and shall be mechanically and electrically interchangeable. Circuit breakers of different current rating shall not be interchangeable.
- Circuit breakers shall be motorized and of 3 pole type and fully with draw able. The shutter plates over the bus bar and circuit orifices shall be arranged to close when the moving part is drawn out.
- Mechanical interlocks shall be provided to move the shutters before the draw-out and draw-in operations of circuit breaker. It shall be possible to operate and lock individually the shutter plates in both their closed and opened positions. Independent manual operation of shutters shall be possible.
- Cable earthing and busbar earthing switches with fault make capacity corresponding to the rated short circuit current shall be provided and may be integral, or separate panels. If integral, the operating handle of die earthing switch snail is an anti-reflex handle. An insulated rod shall be provided between the operator and earthing switch. This operation handle is to be clearly labeled "EARTH SWITCH" and to indicate ON and OFF and the direction of movement to these positions.
- Push buttons shall be fitted with hinged covers to prevent accidental operation.

The labeling on various components of MV switchgear snail is provided such that no ambiguity is found during operation according to the following guidelines (as applicable):

- Blank circuit labels shall be fixed on the front and back panels of the switchgear. Labels shall be of a laminated material to enable the engraving of black letters on a white background.
- "Spring charged" and "Spring discharged" shall be indicated by these words with black lettering on white and yellow background respectively.
- Semaphore indication of the circuit breaker condition shall be. Labeled ON in white letters on a red background and OFF in white letters on a green background.
- The circuit shutters shall be painted yellow and have "CABLE" painted on them in white lettering. The bus bar shutter shall be painted red and have the word "BUSBAR" painted on it in white colour.

- The two bus bar shutters on the bus-section shall be painted red and, in addition to the word "BUSBAR" painted on in white, an arrow pointing in the direction of the respective bus bar.
- The push buttons used for opening and closing the circuit breaker shall be labeled "Push for ON" and "Push for OFF" in white letters on blue background. Safety interlocks in MV switchgear shall be provided to prevent the following situations:
- Moving the breaker unit from the "disconnected" position to the service position without all auxiliary supplies being connected.
- Uncoupling the auxiliary supplies while the breaker unit is in the "service" position.
- Withdrawing the breaker unit past the "disconnected" position before auxiliary supply plugs and sockets have been uncoupled.
- Moving the breaker unit from the service or disconnected position while the circuit breaker is closed.
- Closing of the circuit breaker when the breaker unit is between the disconnected and service position.
- Moving the breaker from the disconnected position to the service position while the earthing switch is closed.
- Closing the earthing switch when the breaker unit is in service position or between the service and disconnected position.
- Paralleling of the two incoming services with the bus section breaker closed.

Bus bars:

The bus bar system of the MV switchgear shall be suitable to withstand mechanical stress for rated short circuit currents. The bus bars, connections and their insulated supports shall be of approved construction and mechanically strong with moulded insulation completely encasing each bus bar and connections.

Compensation for expansion and contraction of the bus bar and enclosure arrangement due to temperature changes shall be provided.

Bus Section Unit:

The bus section unit of MV switchgear shall be provided with circuit breakers, earthing switch, CTs, relays, indication lamps, etc.:

- The Circuit Breaker shall be of 3 pole type rated for an ambient temperature of 50°C and shall conform to the following requirements:

a. System Nominal Voltage : 5.5 Kv.

b. Basic Impulse Level (BIL) : 60kV

c. Total break time : Less than 3 cycles

Percentage dc component : As per IEC 62271-100

d. Frequency : 50Hz

as specified in the Schedules and BOQ

f. Control Voltage : 48Volts, DC

g. Spring Charge Voltage : 48Volts, DC

- A bus bar earthing switch shall be provided beside the bus-section circuit breaker so that each section of bus bar can be earthed.

- Current transformers shall be provided with 3 x 630/5 CTs each side of the bus section circuit breaker to give three zones of stuck breaker protection.
- Relays shall be flush mounted on the front panel. Details of the required relays and connections shall comply with the requirements.
- A three position, trip / normal / close switch for local tripping and closing of the circuit breaker shall be provided.
- Provide lamp test switch (to check healthy lamp condition for all indication lamps) with positions normal and test. The switch shall have spring return to normal position.
- Suitably rated long life low burden 48 Volts DC indication lamps shall be provided to indicate the status of circuit breaker and earth switch as follows:- a. Green Lamp: Circuit Breaker OFF. b. Red Lamp: Circuit Breaker ON. c. Orange Lamp: Earth Switch ON.
- Terminals shall be provided in an external cable connection box at the rear of the panel. Sufficient terminals shall be provided to terminate 2 x 12 core 2.5 mm² PVC / SWA / PVC cables. (Incoming control supplies 48 Volts DC and 380 Volts AC 3 phase 50 Hz). Termination for 2 x 4 core cables associated with the stuck breaker protection shall also be provided for. The control supplies shall be wired from the connection box terminals to terminals in the front panel and from there bussed to adjacent panels.
- Main Bus:
 1. The main bus shall be tin plated copper and rated as indicated in drawings. Bus bars shall have a continuous current rating based on temperature rise and documented by design tests. All joints will be in plated with at least 2 bolts per joint. Bus bars will be braced to withstand magnetic stresses developed by currents equal to main power circuit breaker close, carry, and interrupt ratings. Access to bus bars shall be through removable front panels. Bus bars shall have fluidized bed epoxy flamed retardant and non-hydroscopic insulation with a continuous current rating.
 2. A ground bus (1/4 by 2 inch copper) shall extend throughout assembly with connections to each breaker grounding contact and cable compartment ground terminal. Joints shall be made up as indicated in drawings. Station ground connection points shall be located in each end section.
- The incoming unit of MV switchgear shall comprise circuit breaker, incoming cable earthing, current and voltage transformers, protection and control relays, meters and instrumentation and shall conform to the requirements as detailed hereunder
 1. The circuit breaker and earthing switch shall be provided according to the requirements given above for bus-section unit.
 2. Current transformers shall be of epoxy resin encapsulated design and be capable of 20% overload and shall have 5 Amps secondary. Shrouded CT test links shall be provided on the front panel. All CTs shall be fully rated in accordance with the data given for the circuit breaker. All CT wiring shall be terminated in the rear mounted multi-core cable box. CTs shall be delivered short circuited.
 3. Voltage transformers shall be of electromagnetic epoxy encapsulated dry type design and rated as follows :- a. Vector Group: Y-Y b. Rated Voltage Factor: 1.9 c. Primary Voltage: 5.5 Kv, 3 phase, 50Hz. d. Secondary Voltage: 400 or 230V, 50Hz. The secondary windings of voltage transformers shall be wired to fuse and links in the front panel 3 x 5A fuses are required for two phases (E10, E50) and 3 links for the other phase (E30). The links should be solidly earthed, mounted in the circuit breaker control compartment.
 4. Protection and control relays shall be provided for IDMT over-current, earth fault and differential protection in accordance with IEC standards. Protection relays shall be flush mounted on the front of the MV Switchgear. The tripping circuit of the circuit breaker shall be extended to the rear mounted multi-core termination box to

facilitate the connection of a trip signal from the remote protection relays if required in the future. 5. All meters and instruments shall be flush mounted on the front of switch panel. One voltmeter with switch is to be provided to read R-Y, Y-B, B-Y (phase to phase) volts. An OFF position shall be provided. The full scale deflection shall be 20kV with a red line marked at 5.5 kV. The voltmeter shall be connected to the voltage transformer. One Ammeter with selector switch or three individual ammeters shall be provided to read R, Y, B scaled to the maximum expected current range to measure phase currents. The ammeters shall be connected to the current transformers.

6. Cable boxes shall be provided with sufficient terminals to terminate 3 x 12 cores and 1x4 core 2.0mm² PVC/SWA/PVC multi-core cables as needed by manufacturer recommendations .

The feeder unit(s) of MV switchgear shall comprise circuit breaker, cable earthing switch, current transformers, protection and control relays, meters and instrumentation and shall conform to the requirements as detailed hereunder: -

- The circuit breaker, earthing switch and current transformers for instrumentation and protection shall be provided according to the requirements given above for bus-section unit.
- Protection and control relays shall be flush mounted on the front panel. As a minimum, relays shall be provided for IDMT over-current and earth fault protection in accordance with standards.
- All meters and instruments shall be flush mounted on the front of switch panel. One ammeter (flush fitting) with selector switch for phase currents and one thermal maximum "demand indicator meter (30 minutes time lag) full scale deflection to 600 or 400 Amps or as required to suit the site installations, shall be provided. These ammeters shall be connected to the CTs.
- Cable boxes shall be provided with sufficient terminals to terminate 1 x 12 cores 2.5 mm² PVC / SWA / PVC multi-core cable in accordance with the requirements.

All the MV cables in MV switchgear shall be connected in accordance with the requirements given in Section Medium Voltage Cables and Accesories. The standard method of cable termination is using compression terminal lugs and heat shrink insulation.

All panel wiring shall have a minimum cross section of 2.5 mm² for current circuits and 1.5 mm² for potential circuits. Conductors shall have a minimum of 3 strands per conductor. Wiring numbering shall be in accordance with the drawings attached to the Specifications.

In addition to the contacts already specified and required for various operations, 2 spare normally open and 2 spare normally closed contacts shall be provided for each MV circuit breaker.

H.31.2.3 Load Breaker Switch (If Used)

- General

Load Break Switch shall be incorporated with HRC fuses, load break switches shall interrupt currents up to their rated currents as well as they shall handle short circuit currents.

All load break switches shall be motorized and fixed.

- Operation

Load Break Switches shall operate on the vertical break principle with enclosed hard gas arcing chamber. During the operation cycle of the movable contact arm, pilot electrical maintains current flow through the isolating gap. The switching arc is drawn inside a hard plastic arcing tube, forming a cylinder in which the movable contact acts as piston.

Gas released from the cylinder wall during arcing, and forced into the break by pumping action of the piston de-ionizes the switching gap at neutral zero.

At the end of the movable contact arm travel, the pilot electrode shall open and establish the visible isolation gap the safety codes require. During closing, the pre-strike arc is carried momentarily by arcing horns on the top of the main movable contacts.

- Operating Mechanism

Operating mechanism shall consist of stored energy opening and closing mechanism and electrical motor operation.

Shunt trip coils and mechanical releases shall be provided for fuse strike Pins.

Earthing Switches shall be added on line and load side. All auxiliary contacts shall be provided for remote position indications

- Technical Description a. System Nominal Voltage : 5.5 Kv. b. Basic Impulse Level (BIL) : 60kV c. Total break time : Less than 3 cycles Percentage dc component : As per IEC 62271-100 d. Frequency : 50Hz as specified in the Schedules and BOQ f. Control Voltage : 48Volts, DC g. Spring Charge Voltage : 48Volts, DC
- High Voltage HRC Fuses

High voltage HRC fuses shall be highly current limiting silver alloy fuses for short circuit protection. Typical arcing times shall be less than 10ms, max, let through currents are between 0.12 and 7 KA. The main fusible links shall be made from precisely calibrated silver alloy stampings. These are wound around ceramic cylinders which are embedded in quartz sand for arc extinction.

A secondary spring loaded fusible links retains the striker pin indicator inside the outer protection sleeve. The entire element is entirely sealed with silver plated brass caps which are also serve as contact elements for the fuse clips.

Suitable fuse bases and carriers shall be available for attachment to load break switches.

H.31.2.4 DC Battery and Charger

The DC battery and charger equipment shall be supplied for the control and protection of MV switchgear and manufactured according to the latest provisions of the applicable NEC and IEC standards.

The DC battery and charger equipment shall be suitable for the climatic conditions given in Section General provisions for electrical work.

The charger unit shall be housed in a self-contained, floor or wall mounted sheet metal enclosure to EP41. The battery shall be mounted on a separate steel frame for ease of maintenance. Adequate ventilation of the battery shall be provided.

The battery shall provide sufficient power at 48 Volts DC (or any other voltage as indicated on the Contractor's approved shop drawings) to close or trip all the breakers in MV switchgear simultaneously and maintain other loads in the switchgear. Any future breakers shall be taken into consideration when sizing the battery and charger.

The battery shall comprise required number of nickel-cadmium cells at 1.2 Volts / cell with potassium hydroxide electrolyte. Each cell shall be constructed in a semitransparent plastic container. The battery shall have a nominal output voltage of 48 Volts DC or any other voltage as indicated on drawings. The calculations for the capacity of the battery shall be submitted for approval of supervising Engineer. The electrolyte level of all cells shall be visible.

The charger unit shall be automatic constant voltage float / boost type, with solid state electronics employing silicon voltage reference diodes and rated as follows:-

- Input Voltage - 230 Volts, 50 Hz.
- 48 Volts DC (or as specified in the Schedules and BOQ).

- Charging Current - Adjustable 10% to 105%.
- Stability - Float Voltage $\pm 1\%$; for mains variations $\pm 10\%$.
- Smoothing - Approximately 2% RMS.
- Recharge Float Voltage - 1.44 Volts / Cell.
- Boost Voltage - 1.68 Volts / Cell.

The mains input of the DC battery and charger shall be connected via a suitably rated circuit breaker. Circuit breakers shall also be provided for battery isolation and isolation to the DC distribution panel. An electronic current limit shall be provided at 105% of the rated output current.

A high-low voltage output relay shall provide an alarm when the output voltage falls to 80% or rises to 120%. An AC failure and DC failure alarm shall also be provided. All these alarms shall be provided locally as well as at a remote location, where 24 hour attendance is available as approved by the supervising Engineer.

The meters, switches and indications shall be provided at the front of the charger unit according to NEC. These shall include, but not be limited to, the following:-

- Moving coil DC voltmeter and ammeter for battery.
- A float / boost switch.
- Green neon to indicate that the charger is operating on FLOAT.
- Red neon to indicate that the charger is operating on BOOST.

The battery shall be delivered empty of electrolyte. Sufficient quantities of distilled water and electrolyte in crystalline form shall be delivered for the first filling of the battery

H.31.2.5 Cable Glands

Provide cable glands for the termination of MV XLPE cables at MV switchgear. Cable glands shall provide an adequate, corrosion resistant earth bond for the metallic cable armour together with means of sealing the cable sheath terminations.

The cable glands shall be designed to accommodate MV XLPE cables of all sizes specified under the Contract and main incoming supply cable by Local Electrical Co.. The particular option regarding cable dimensions are summarized in the table below:

Cable Size (mm ²)	Diameter underneath the Armour (mm)	Diameter of Armour Wires (mm)
300	70	2.5
240	67	2.3
185	64	2.0
50	57	1.6

The cable glands shall allow enough space inside the switchgear cable box to allow cross core connection and easy interchange of phase.

Contact between amour and cable gland shall be ensured by two worm drive clips. This contact should be designed to withstand 21 kA for 3 seconds.

A PVC shroud and stud (M10) shall be provided with the cable gland to connect an earthing cable. Adequate nuts and washers shall be provided as required on site.

H.31.2.6 Accessories

Include as part of the main tender price, all necessary equipment and accessories required assembling individual units to form complete MV switchgear. These shall include all necessary small wiring, fuses, foundation fixing details, labels, cable termination facilities, sole-plates, bus bar interconnections, terminal boards and all necessary sundries.

A wall mounted encapsulated single line schematic diagram showing the operational positions of the unit shall be provided, which shall be black on a white or silver background.

Supply MV switchgear complete with all accessories necessary to form a complete installation including, but not be limited to, the following operation and safety accessories:

- 2 Circuit breaker raise / lower or driving handles.
- 1 set of high voltage test bushings.
- 2 Sets of jumper connections.
- Circuit breaker manual charging handle.
- Set of special tools including circuit breaker trolley for removal and insertion of circuit breakers.
- 2 pairs of insulating gloves.
- Notice / safety instructions and first aid chart for electric shock.
- 1 rubber mat 35 mm thick, 1 m wide, extending full length of MV switchgear. The mat shall have corrugated surface with a dielectric strength of 40 kV minimum with 3000 volts to ground.
- Sufficient padlocks with 6 mm shackles having 24 mm clearance.

The supplier shall provide a complete set of drawings for MV switchgear(s). The drawings shall include:

- General arrangement of circuit breaker.
- Schematic diagram for each type of breaker.
- Wiring diagram for each type of breaker.
- Multi-core cable schedules.

Six paper print copies of these drawing sets shall be provided and one complete set of transparency copies.

In English language 6 copies of a combined operating and instruction manual, describing the modes of equipment operation and the necessary on-site maintenance of all items provided. Submission of these manuals should be before shipment of the equipment.

Testing:

- The switchgear equipment and circuit breakers shall receive factory production test as listed below:

1. Equipment	
	a. Low frequency dielectric test.
	b. Grounding of instrument cased.
	c. Control wiring and device functional test.
	d. Polarity verification.
	e. Sequence test.
	f. Low frequency withstand voltage test on major insulation components.
	g. Low frequency withstand test on secondary control wiring.

2. Breakers:	
	a. Coil check test.
	b. Clearance and mechanical adjustment.
	c. 300 Electrical and mechanical operation test.
	d. Timing test.
	e. Conductivity of current path test.
	f. Hi-potential testing of breaker.

g. Vacuum bottle integrity test.

- Manufacturer shall provide to the Engineer documents verifying completion of factory production tests.

Finish:

All steel surfaces shall be chemically cleaned and given an iron phosphate corrosion resistant treatment providing a strong bond for paint adhesion. All parts shall be immersed in paint applying 0.7-0.8 mils of cathodic epoxy paint electrically bonded to all surfaces for maximum adhesion. The finish shall be cured in an oven at to insure maximum toughness and prolong service in severe environments.

H.31.3 Execution

H.31.3.1 Inspection

Examine installation area to assure there is enough clearance to install switchgear.

Verify that medium voltage metal clad switchgear is ready to install.

Verify field measurements are as instructed by manufacturer.

Examine the MV switchgear room and other associated areas and conditions under which the equipment is to be installed, and correct any unsatisfactory conditions detrimental to the proper and timely completion of the work. Do not proceed with the work until unsatisfactory conditions have been corrected in a manner acceptable to the Engineer.

Agree with the manufacturer of the switchgear, the suitability of the civil works for foundations which must be compatible with equipment and all sizes and details must be checked and confirmed before concrete is poured, or revised with the approval of the Engineer where necessary.

H.31.3.2 Installation

The installation of MV switchgear shall be in accordance with the manufacturer's written instructions and shall comply fully with the requirements of IEC, NEC.

It is the Contractor's sole responsibility to supply all materials and to construct in the correct location, level and true grade, the concrete base, and to connect all incoming and outgoing cables.

Install the MV switchgear using the appropriate lifting equipment to ensure that no damage occurs. When correctly located, the unit shall be anchored in position and tested before and after connecting the incoming and outgoing cables.

H.31.3.3 Field Quality Control

Field inspection and testing will be performed.

Dielectric strength or insulation resistance test of completely assembled MV switchgear after installation shall be performed.

Inspect installed switchgear or anchoring, alignment, grounding and physical damage.

Check tightness of all accessible electrical connections with a calibrated torque wrench. Minimum acceptable values are specified in manufacturer's instructions.

Megger and record phase to phase and phase to ground insulation resistance of each bus section. Megger for 1 minute for each measurement at minimum voltage of 1000VDC. Measured insulation resistance shall be at least 1 megohm(s).

Test each key interlock system for proper functioning.

Perform tests to prove the operation of all MV circuit breakers, simulate fault on protective relays and devices.

Current injection test of all protective relays and devices shall be carried out.

Perform ratio tests and other field tests of all current and voltage transformers according to IEC requirements.

Complete functional and trip testing of battery and charger unit including battery discharge test, float and boost charging functions, etc.

H.31.3.4 Adjustments

Comply with Section

Adjust protective relays and devices to provide adequate over current protection and selective tripping with downstream devices according to short circuit and protection co ordination study and after proper co-ordination with protection settings of Electricity Supply Authority.

H.31.3.5 Cleaning

Clean interiors of switchgear to remove construction debris, dirt, shipping materials.

Repaint scratched or marred exterior surfaces to match original finish.

H.32. MEDIUM VOLTAGE SWITCHGEAR

H.32.1 General

H.32.1.1 Section Includes

Medium Voltage (24 kV) switchgear and associated equipment including, but not limited to, the following:

- MV (24kV) metal clad switchgear.
- DC battery and charger.
- Cable glands.
- Accessories.

H.32.1.2 References

- IEC 60099 Surge Arrestors
- IEC 60376 Sulphur Hexafluoride
- IEC60044-1 Instrument Transformers – Part 1 Current Transformers

- IEC60044-2 Instrument Transformers – Part 1 Inductive voltage transformers
- IEC 60255 Electrical Relays.
- IEC 60529 Degrees of Protection of Enclosures.
- IEC60071 Insulation Coordination
- IEC62271-1 Common Specifications for high voltage switchgear and control gear Standards
- IEC-6227-200 Metal Clad Switchgear
- IEC61171-103 High Voltage switches for rated voltages above 1kV and less than 52kV
- IEC 62271-105 High voltage alternative current switch-fuse combinations.
- IEC 62271-100 High voltage alternating current circuit breakers.
- IEC 62271-102 High voltage alternating current disconnectors and earthing switches.
- IEC61850 Communication Networks and Systems in Substations

H.32.1.3 Submittals

Product Data: Submit full technical data of equipment for approval including, but not limited to, the following:

- Manufacturers' catalogues, detailed description of construction, provisions for extension, compliance with the Standards, dimensions and weights, operating characteristics, operating curves and error curves (VT, CT) for all switchgear, control gear, protective gear, metering gear etc.
- Details of miscellaneous items including pilot lights, cabling or wiring, incoming and outgoing feeder terminal fittings, supports, labels, interlocks, bracing etc.

Shop and Construction Drawings: Submit drawings for approval including, but not limited to, the following:

- Plans and elevations, with indication of switchgear mounted components, dimensions and weights.
- Arrangement of equipment and general layouts.
- locations of protective gear (relays, metering instruments, CTs, VTs) etc.
- Schematic and elementary diagrams of control circuits.
- Block diagrams for BMS interface points
- Foundation details, grouting holes and installation details.
- Physical arrangement of incoming and outgoing feeders, instrument transformers, busbars, connections etc.
- Dimensions and weights of control power supply and other auxiliary equipment or components.

Point-wise compliance statement to the specifications, duly signed by the manufacturer /manufacturer's authorized representative and the contractor.

Calculation of current and voltage transformers characteristics to verify their suitability for proper unsaturated operation under site fault condition and their adequacy for relay /wires/metering requirements

Technical Literature: Submit the following for approval prior to equipment manufacture:

Schedule of selected circuit breakers, relays and control gear, with complete identification of each component and its characteristics.

Type Test Certificates: Submit to verify compliance of main equipment with the relevant IEC Standards, including the following:

- Impulse withstand-voltage tests

- Power frequency withstand-voltage tests.
- Temperature-rise tests.
- Short time current tests.
- Verification of making and breaking capacity.
- Mechanical endurance/operation tests.
- Verification of degrees of protection for persons against contact with live and moving parts.
- Internal arc tests.
- Protection degree test to IEC 60529.

Routine Tests: Each complete switchgear unit is to undergo routine tests at the manufacturer's works in accordance with the relevant standards. Submit routine test reports, prior to shipping equipment, indicating ambient test conditions and guaranteed rating of equipment under site conditions.

Qualification Data: For firms and persons specified in "Quality Assurance" Article.

Field Test Reports: Indicate and interpret test results for compliance with performance requirements.

Maintenance Data: For switchgear to include in the maintenance manuals.

Coordination Study: Submit protection coordination study, including pick-up settings and time-grading, together with time-current curves and range of adjustments etc. as required to coordinate with upstream and downstream protective devices of the complete system based on coordination curves of protective devices used and specific calculated prospective short circuit currents at various points.

WARRANTY

Manufacturer warrants equipment to be free from defects in materials and workmanship for 1 year from date of handing over the project.

H.32.1.4 Delivery, Storage, and Handling

Deliver in shipping splits of lengths that can be moved past obstructions in delivery path as indicated.

Store so condensation will not form on or in switchgear.

Apply temporary heat where required to obtain suitable service conditions.

Handle switchgear using factory-installed lifting provisions.

H.32.1.5 Extra Materials

Spare Parts: Provide spare parts, as recommended by the manufacturer, for one year maintenance as expected under local conditions, and to allow for emergency replacement due to accidental breakage or failure. Spare parts are to include, but are not limited to, the following:

- Two sets of each type of lamp, fuse, auxiliary switch, trip coil, control switch, selector switch, neon indicator and the like.
 - Complete set of main contacts of each rating.
 - Complete set of breaker/switch auxiliary contacts.
 - Complete mechanism of breaker/switch of each type.
 - Drive motor of each type
- Tools and Instruments: Provide tools and instruments required for normal routine inspection, testing, operation and maintenance including levering crank, manual charging handle, manual shutter

operator, testing jumpers and HV test bushings, set of rail extensions, digital micro ohm-meter, set of mobile lifting and handling equipment etc. as necessary for the type of switchgear.

H.32.1.6 Factory Acceptance Tests

Factory acceptance tests of equipments under this Contract are subject to be witnessed by the Engineer. The Contractor is to include in his price the costs for one factory witness test visit in manufacturer premises for two persons from the Engineer/Employer side, including travel on business class flights and all costs of five stars hotel accommodation, local transportation and test expenses

H.32.2 Products

H.32.2.1 General

All material is used in the manufacture and installation of MV switchgear shall be of high quality and of proven suitability for the functions they will perform and the conditions they will meet in service.

For remote monitoring / controls, comply with the requirements.

H.32.2.2 Manufacturers

The listing of specific manufacturers above does not imply acceptance of their products that do not meet the specified ratings, features and functions. To eliminate possible disputes between circuit breaker and switchgear coordination, the manufacturer of the switchgear shall also be the manufacturer of the circuit breaker. Manufacturers listed above are not relieved from meeting these specifications in their entirety. Products in compliance with the specification and manufactured by others not named will be considered only if pre-approved by the Engineer ten (10) days prior to bid date.

H.32.2.3 MV (24 kV) SWITCHGEAR (all components are motorized even if not shown on the Contractor's approved shop drawings)

Parameters

The MV switchgear shall be constructed based on following system parameters

- Voltage : 24kV, 3 phase.
- Frequency : 50Hz
- Basic Impulse Level (BIL) (1.2/50microsecond peak) : 125kV
- Symmetrical Fault Level : 25kA RMS (3 second)
- Neutral : Resistance earthed.
- Loss of service continuity : LSC-2B
- Partition Class : PM
- Internal Arc Classification : AFLR
- Internal Arc Rating : 25KA-1s
- Operating Sequence : O-0.3s-CO-15s-CO
- Mechanical Endurance : M2
- Electrical Endurance : E2

These are requirement by standard, and the manufacturer shall state the same

H.32.2.4 Indoor Fixed Metal-Clad Switchgear

Type: For installation indoor categorized, multi compartments with insulated or metallic partitions, comprising Single busbar, floor mounted, free standing switchgear of modular construction, forming a continuous integral structure extendable at either end, with withdrawable motorized mounted circuit breakers, disconnecter combination, isolating disconnectors, and/or switch -disconnecter-fuse combination, as specified.

Switchgear is to have a degree of protection, against contact with live parts and against external effects, of IP3X for enclosures and IP 4X for partitions according to IEC 62271-1 and IEC 60529, when in the connected position.

Circuit breakers are to be frame mounted and bolted into position. Frame is to have wheels for handling during installation or maintenance.

Busbars: high conductivity, electrolytic copper, modular, design to withstand worst short- circuit conditions without allowing permissible temperature rise at ambient conditions to be exceeded, in accordance with the Standards. Busbar connection from one unit of switchgear to another is to be expansion/contraction compensated, plated and bolted. Busbar supports are to be flame-retardant, track-resistant, glass polyester, porcelain or equally reliable fibre glass reinforced epoxy to approved standards.

Busbars: are to be insulated, either with epoxy insulation applied by the fluid-dip process or heat shrinkable insulating sleeves. Busbar connections are to be insulated with easily installed, preformed vinyl boots, secured by nylon hardware.

Single air-break /SF6 isolator is to be provided, on busbar side of circuit breaker, interlocked with circuit breaker operation such that isolation or connection of circuit breaker is not possible while circuit breaker is closed. Isolators are to be pad lockable in the off and earth positions.

Compartmentation is to be provided by insulated or earthed metallic partitions between switching devices, busbars, cable terminations and LV equipment.

Mechanical interlock between the door and the switch disconnector's "Earth Position" is to be provided.

Control and monitoring of each unit is to be provided on front panel and is to include mimic diagram, operating handles of main device and earthing switches, position indicators, close and trip push buttons, potential indicators, identification and instruction plates, protective devices, metering and indicating instruments, key and pad lockable devices, as specified and shown on the Contractor's approved shop drawings.

Access to LV wiring is to be from front of cubicle for control, protection, test terminal blocks and associated LV power connections. Multi-pin, disconnectable, lock-in type plug and socket arrangement is to be provided between circuit breaker and stationary part of cubicle.

Anti condensation heaters with thermostat, switch and pilot lamp, and of rating recommended by manufacturer are to be provided in each section of switchgear assembly

Wiring diagram, suitably protected and located inside LV compartment of each unit, is to indicate all data and components related to the particular unit and its external circuitry.

Anti-slip, synthetic, insulating, rubber mat, minimum 5 mm thick and 900 mm wide, with heavy canvas lining on lower face, is to be provided for full length in front of switchgear assembly.

Labeling The labeling on various components of MV switchgear shall be provided such that no ambiguity is found during operation according to the following guidelines:

- Blank circuit labels shall be fixed on the front and back panels of the switchgear. Labels shall be of a laminated material to enable the engraving of black letters on a white background.

- "Spring charged" and "Spring discharged" shall be indicated by these words with black lettering on white and yellow background respectively.
- Semaphore indication of the circuit breaker condition shall be labeled ON in white letters on a red background and OFF in white letters on a green background.
- The circuit shutters shall be painted yellow and have "CABLE" painted on them in white lettering. The busbar shutter shall be painted red and have the word "BUSBAR" painted on it in white colour.
- The two busbar shutters on the bus-section shall be painted red and, in addition to the word "BUSBAR" painted on in white, an arrow pointing in the direction of the respective busbar.
- The push buttons used for opening and closing the circuit breaker shall be labelled "Push for ON" and "Push for OFF" in white letters on blue background. Safety interlocks in MV switchgear shall be provided to prevent the following situations: a. Moving the breaker unit from the "disconnected" position to the service position without all auxiliary supplies being connected. b. Uncoupling the auxiliary supplies while the breaker unit is in the "service" position. c. Withdrawing the breaker unit past the "disconnected" position before auxiliary supply plugs and sockets have been uncoupled. d. Moving the breaker unit from the service or disconnected position while the circuit breaker is closed. e. Closing of the circuit breaker when the breaker unit is between the disconnected and service position. f. Moving the breaker from the disconnected position to the service position while the earthing switch is closed. g. Closing the earthing switch when the breaker unit is in service position or between the service and disconnected position. h. Paralleling of the two incoming services with the bus section breaker closed.

Busbars: The busbar system of the MV switchgear shall be suitable to withstand mechanical stress for rated short circuit currents. The busbars, connections and their insulated supports shall be of approved construction and mechanically strong with moulded insulation completely encasing each busbar and connections.

Compensation for expansion and contraction of the busbar and enclosure arrangement due to temperature changes shall be provided.

Bus Section Unit: The bus section unit of MV switchgear shall be provided with circuit breakers, earthing switch, CTs, relays, indication lamps, etc

The circuit breaker shall be of SF6 Vacuum Type Complying with IEC 62271-100 type suitable for indoor installation. The breaker shall be best and modern in design and shall be supplied with all the associated equipments including fittings and wiring etc. The breaker shall be suitable for three phase auto re-closing operation.

The breaker compartment of the cubicle shall be designed to have fully draw out self contained truck arrangement with breaker mounted on the same.

The circuit breaker shall be provided with rapid and smooth interruption of current under all conditions completely suppressing all undesirable phenomenon even under the most severe and persistent short circuit conditions or when interrupting small leading and lagging currents. The detail of any device or special feature incorporated to limit or control the rate of rise of re-striking voltage across the circuit breaker contact shall be stated. The over-voltage caused by the circuit breaker switching on inductive and capacitive load shall not exceed 2.5 times the normal phase to neutral voltage. The total break time for the circuit breaker throughout the range of its operation duty shall be stated in the tender and it shall be guaranteed.

All parts of the circuit breaker unit shall be mechanically designed to withstand all mechanical, electrical and other stresses which may be experienced in the operation of the unit including those under short circuit conditions.

Sulphur Hexa fluoride (SF-6) Circuit Breakers

The circuit breakers shall be of Sulphur Hexa fluoride (SF-6) gas filled, single pressure puffer sealed tank type suitable for indoor duties. Vacuum breakers are also accepted. Each pole of the circuit breaker shall have an interrupting chamber filled with SF-6 gas encapsulated in porcelain insulator housing independent of the other two poles. The gas pressure shall be monitored and regulated by suitable pressure switches. The design and construction of the circuit breaker shall be such that there is minimum possibility of gas leakage and ingress of moisture, there should not be any condensation of SF-6 gas on internal insulating surfaces of circuit breaker. Suitable sealing arrangement shall be provided on each static joint to have proper sealing of SF-6 gas. An alarm shall be given if the gas density fails to a pre-set value and if it falls further to a specified minimum the breaker shall be blocked. The material used in the construction of circuit breaker shall be fully compatible with SF-6 gas. All similar parts including poles of the circuit breaker shall be interchangeable.

1. The Circuit Breaker shall be of 3 pole type rated for an ambient temperature of 50°C and shall conform to the following requirements:.

a. System Nominal Voltage : 24kV	
b. Basic Impulse Level (BIL) : 125kV	
c. Power Frequency Withstand Voltage : 50kV	
d. Rated short time withstand current : 25kA – 3 sec	
e. Frequency : 50Hz	
f. Rated Normal Current at 50°C : 630Amps	
	– Rated Normal Current: As specified in the Schedules and BOQ.
	– Rated Short-Circuit Breaking Current at Nominal Service Voltage and Percentage D.C. Component
	in Accordance with IEC 62271: 25 kA.
	– Rated Short-Circuit Making Current (peak): 63 kA.
	– Rated Duty Operating Sequence: 0-0.35-CO-15S-CO
g. Control Voltage : 110Volts, DC	
h. Spring Charge Voltage : 110Volts, DC	

2. Operating Mechanism

The breaker shall also pass the operational test which ascertain the capabilities of operating mechanism. The motor compressed spring mechanism shall consist of a closing spring which is wound or compressed by an electric motor immediately after the breaker closes. The closing action shall also wind or compress a tripping spring and shortly after the breaker is closed both springs shall be wound. After the breaker has tripped, the tripping spring shall remain in there leased position as long as the breaker is open, but the closing spring shall remain wound and ready for closing operation. The operating mechanism shall have all the necessary auxiliaries, apparatus for operation and supervision, like motor starter with thermal overload release, one closing coil, two trip coils, push button for local electrical operation, push button for direct mechanical tripping auxiliary switches, anti pumping contactors, operation counter, socket for inspection, lamp and heater with switch. In addition mechanical interlocking system for interlocking with other associated breaker shall be provided. Details of operation logic and other interlocking scheme is given under Clause No.2.10.2. Spring charging motor shall be standard single phase motor suitable for operation on 110V DC. Supply. Provision shall also exist for one detachable handle for manual charging in the event of failure of auxiliary supply. The mechanism shall be suitable for remote operations. In addition auxiliary local operating mechanism shall be trip free. a-

Operating voltage for closing/tripping coils shall be 110VDC. The supply shall be available in the sub-station. b- Operating voltages for heater elements shall be 230 VAC, 50 Hz. A.C. supply which shall be made available at site.

3. Type: SF6 circuit breaker using rotating arc or puffer principle, with closed gas circuit, and with pressure detector to prevent operation of circuit breaker in case of loss of gas pressure within the sealed enclosure.
4. SF6 breakers, are to be provided with gas filling valve and with pressure switches, one per pole, to initiate alarm in case the pressure of the SF6 gas drops below manufacturer set values.
5. A busbar earthing switch shall be provided beside the bus-section circuit breaker so that each section of busbar can be earthed.
6. Current transformers shall be provided with 3 x 630/5 CTs 5P10 each side of the bus section circuit breaker to give three zones of stuck breaker protection.
7. Relays shall be flush mounted on the front panel.
8. A three position, trip / normal / close switch for local tripping and closing of the circuit breaker shall be provided.
9. Interrupter

Each pole of circuit breaker shall be provided with a SF6 interrupter sealed for life and encapsulated by ceramic insulators. The interrupter shall be provided with steel chromium arc chamber to prevent vaporized contact material being deposited on the insulating body. A further shield giving protection to the metal bellow shall be provided. The metal bellows shall follow the travel of the moving contacts to seal the interrupter against the surrounding atmosphere.

10. Recovery Voltage and Power Factor

The circuit breaker shall be capable of interrupting rated power with power frequency recovery voltage equal to the rated maximum line to line service voltage at rated frequency and at a power factor "equal to or not exceeding 0.15" as per IEC 56-1987. In case of multiple break circuit breaker, devices/method adopted to all the breaks shall be indicated and actual voltage distribution recorded during interruption tests shall be furnished with the bid.

11. Transformer Charging Circuit Breaking Capacity

The breaker shall be capable of interrupting inductive currents, such as those occurring while switching off unloaded transformers, without giving rise to undue over voltage and without re-strikes. The maximum over voltage value, which will not be exceeded under such conditions shall be stated in the tender.

12. Provide lamp test switch (to check healthy lamp condition for all indication lamps) with positions normal and test. The switch shall have spring return to normal position.
13. Suitably rated long life low burden 48 Volts DC 110V DC indication lamps shall be Provided to indicate the status of circuit breaker and earth switch as follows:-

a. Green Lamp: Circuit Breaker OFF. b. Red Lamp: Circuit Breaker ON. c. Orange Lamp: Earth Switch ON.

14. Terminals shall be provided in an external cable connection box at the rear of the panel. Sufficient terminals shall be provided to terminate 2 x 12 core 2.5 mm² PVC / SWA / PVC cables. (Incoming control supplies 48 Volts DC and 400 Volts AC 3 phase 50 Hz). Termination for 2 x 4 core cables associated with the stuck breaker protection shall also be provided for. The control supplies shall be wired from the connection box terminals to terminals in the front panel and from there bussed to adjacent panels.
15. Main Bus:

1. The main bus shall be tin plated copper and rated as indicated in drawings. Bus bars shall have a continuous current rating based on temperature rise and documented by design tests according to IEC62271-200. All joints will be in plated with at least 2 bolts per joint. Bus bars will be braced to withstand magnetic stresses developed by currents equal to main power circuit breaker close, carry, and interrupt ratings. Access to bus bars shall be through removable front panels. Bus bars shall have fluidized bed epoxy flamed retardant and non-hydroscopic insulation with a continuous current rating.
2. A ground bus (1/4 by 2 inch copper) shall extend throughout assembly with connections to each breaker grounding contact and cable compartment ground terminal. Joints shall be made up as indicated in drawings. Station ground connection points shall be located in each end section.

16. TIE BREAKER CHARACTERISTICS AND CONTROL

Tie breaker shown as bus coupler on drawings shall consist of a double isolation disconnectable circuit breaker.

- A. Provide automatic transfer control equipment to transfer a load bus from EDL normal source of supply to Project generator plant source. Voltage sensing on each source shall be three phase with loss of phase protection. All transfer scheme logic shall be incorporated into and executed by a Programmable Logic Controller (PLC). The PLC shall receive the following inputs: source voltage status as sensed by the voltage relays, breaker status (open, closed, tripped on fault) for main and bus tie breakers. Interposing relays shall be provided for interfacing the PLC outputs with the circuit breaker close and trip circuits. Additional PLC outputs shall be provided for local indication of the following: transfer scheme status (auto- blue/manual-white) and PLC fault (amber). If the control power source for the PLC is derived from within the switchgear, provide a dedicated "hold up device" for the PLC to ride through any momentary switching of control power sources. The PLC programs shall be executed without interruption during an under voltage or loss of phase condition.
- B. Basic PLC logic features shall include: interlocking of the main and bus tie breakers to prevent paralleling sources; time delay for initiating a transfer upon an under voltage or loss of phase condition; time delay for return to normal after the under voltage or loss of phase condition has been corrected; and blocking transfer, if the main or bus tie breaker trips due to a fault.
- C. Description of operation-three breaker transfers (main-tie-main), delayed transfer/delayed return. Under normal conditions both main breakers are closed and the bus tiebreaker is open. The transfer system selector switch is in the auto position. When an under voltage or loss of phase condition is detected, the PLC receives an input from the voltage sensing relays. The PLC program executes, tripping the affected main breaker by its interposing trip relay after the programmed time delay. The PLC senses the open main breaker status and the program immediately closes the bus tie breaker by its interposing close relay. With their turn of the affected resource, the PLC trips the bus tie breaker by its interposing trip relay after the programmed time delay. The PLC senses the open tie breaker and the program immediately recloses the open main breaker by its interposing relay. Simultaneous loss of both sources shall not cause any change in breaker status. Upon return of one source, the PLC shall immediately trip the main breaker without voltage and close the bus tie breaker.
- D. Manual operation-Control switches for the main and bus tie breakers are in operative when the transfer system control selector switch is in the auto position. Turning the transfer system control selector switch to the manual position allows the main and bus tie breakers to be manually closed and tripped via their control switches. Electrical interlocking in the breaker close circuits prevents both main breakers and the tie breaker from being closed at the same time. Redundant electrical interlocking, separate from the PLC, shall be provided for the main and tie breakers and shall be operational only when the automatic transfer system is in the manual mode. To transfer the loads from one source to the other, the affected main breaker must first be opened and then the

bus tie breaker can be manually closed. To return to normal, trip the bus tie breaker and recluse the main breaker via their respective control switches.

E. The PLC shall be able to communicate via RS-485 / Mod bus RTU protocol.

The incoming unit of MV switchgear shall comprise circuit breaker, incoming cable earthing, current and voltage transformers, protection and control relays, meters and instrumentation and shall conform to the requirements as detailed hereunder:

1. The circuit breaker and earthing switch shall be provided according to the requirements given above for bus-section unit.
2. Current transformers shall be of epoxy resin encapsulated design Class 1 for measuring and Class 5P10 for protection and be capable of 20% overload and shall have 1 Amp secondary. Shrouded CT test links shall be provided on the front panel. All CTs shall be fully rated in accordance with the data given for the circuit breaker. All CT wiring shall be terminated in the rear mounted multi-core cable box. CTs shall be delivered short circuited.
3. Voltage transformers shall be of electromagnetic epoxy encapsulated dry type design and rated as follows:-
 - a. Vector Group: Y-Y b. Rated Voltage Factor: 1.9 c. Primary Voltage: 20kV, and / or 11kV, 3 phase, 50Hz. d. Secondary Voltage: 400 phase to phase or 231V phase to neutral , 50Hz.

The secondary windings of voltage transformers shall be wired to fuse and links in the front panel 3 x 5A fuses are required for two phases (E10, E50) and 3 links for the other phase (E30). The links should be solidly earthed, mounted in the circuit breaker control compartment.

4. Protection and control relays shall be provided for IDMT over-current, earth fault and differential protection in accordance with EDL standards. Protection relays shall be flush mounted on the front of the MV Switchgear. The tripping circuit of the circuit breaker shall be extended to the rear mounted multi-core termination box to facilitate the connection of a trip signal from the remote protection relays if required in the future.
5. All meters and instruments shall be flush mounted on the front of switch panel. One voltmeter with switch is to be provided to read R-Y, Y-B, B-Y (phase to phase) volts. An OFF position shall be provided. The full scale deflection shall be 24kV with a red line marked at 20kV. The voltmeter shall be connected to the voltage transformer.

Three Ammeter with maximum demand indicator shall be provided to read R, Y, B scaled to the maximum expected current range to measure phase currents. The ammeters shall be connected to the current transformers.

6. Cable boxes shall be provided with sufficient terminals to terminate 3 x 12 cores and 1x4 core 2.0mm2 PVC/SWA/PVC multi-core cables.
- F. The feeder unit(s) of MV switchgear shall comprise circuit breaker, + switch cable earthing switch, current transformers, protection and control relays, meters and instrumentation and shall conform to the requirements as detailed hereunder: -
1. The circuit breaker disconnect switch , earthing switch and current transformers for instrumentation and protection shall be provided according to the requirements given above for bus-section unit.
 2. Protection and control relays shall be flush mounted on the front panel. As a minimum, relays shall be provided for IDMT over-current and earth fault protection.
 3. All meters and instruments shall be flush mounted on the front of switch panel. One ammeter (flush fitting) with selector switch for phase currents and on thermal maximum " "demand indicator meter (30 minutes time lag)

full scale deflection to 600 or 400 Amps or as required to suit the site installations, shall be provided. These ammeters shall be connected to the CTs.

4. Cable boxes shall be provided with sufficient terminals to terminate 1 x 12 cores 2.5 mm² PVC / SWA / PVC multi-core cable.
- G. The standard method of cable termination shall be compression terminal lugs and heat shrink insulation.
- H. All panel wiring shall have a minimum cross section of 2.5 mm² for current circuits and 1.5 mm² for potential circuits. Conductors shall have a minimum of 3 strands per conductor. Wiring numbering shall be in accordance with the drawings attached to the Specifications.
- I. In addition to the contacts already specified and required for various operations, 2 spare normally open and 2 spare normally closed contacts shall be provided for each MV circuit breaker.
- J. Individually mounted disconnect switch – Mechanical endurance shall be 10,000 operations class M2 as per IEC 62271-100 – Electrical Endurance shall be E2 as per IEC 62271

Class		Description		
M	M1	2,000 switching cycles	Normal mechanical endurance	
	M2	10,000 switching cycles	Extended mechanical endurance, low maintenance	
E	E1	2 × C and 3 × O with 10 %, 30 %, 60 % and 100 % I_{sc}	Normal electrical endurance (not covered by E2)	
	E2	2 × C and 3 × O with 10 %, 30 %, 60 % and 100 % I_{sc}	Without auto-reclosing duty	Extended electrical endurance without maintenance of interrupting parts of the main circuit
		26 × C 130 × O 10% I_{sc} 26 × C 130 × O 30% I_{sc} 4 × C 8 × O 60% I_{sc} 4 × C 6 × O 100% I_{sc}	With auto-reclosing duty	

Vacuum circuit breakers can generally make and break the rated normal current up to the number of mechanical operating cycles.

The electrical endurance is different in the new standard and it is according to the short circuit current of the Circuit breaker :

All disconnect switch shall be equipped with their earthing switch and shall be motorized.

Rotating contacts shall be placed in an enclosure filled with 0.4 bar gas for 24kV. It shall satisfy sealed pressure system and seal tightness requirements after factory checking with leakage rate less than 0.1% for 30 years, switch can be in one of three positions.

– Closed – Open – Earthed

The device shall combine breaking and disconnection function. Any accidental overpressure shall be eliminated by the opening of the safety membrane, in which case the gas is directed toward the back of the unit, away from the operator.

Switch shall have voltage presence indication, motor from operating mechanism, auxiliary contacts, visibility for main contacts, pressure indicator device, operation counter, release unit, key type interlock, enlarge LV control cabinet.

Rotating contacts shall be placed in an enclosure filled with 0.4 bar gas for 24kV. It shall satisfy sealed

K. Operating modes of transfer system

Automatic transfer system shall execute only one changeover from the priority channel (EDL) to the backup channel (Project Power Plant). Automatic transfer system shall then remains on that channel.

In the event of a voltage loss on the active channel, automatic transfer system shall be switched to the other channel after a time delay T1. Automatic transfer system shall execute no return, except in case of voltage loss on the new active channel.

After a changeover, return to the priority channel occur if the MV voltage on that channel is restored. The channel that has priority can be defined according to the state of a dedicated digital input.

H.32.2.5 DC Battery and Charger

The DC battery and charger equipment shall be supplied for the control and protection of MV switchgear and manufactured according to the latest provisions of the applicable IEC standards.

The DC battery and charger equipment shall be suitable for the climatic conditions.

The charger unit shall be housed in a self-contained, floor or wall mounted sheet metal enclosure to IP41. The battery shall be mounted on a separate steel frame for ease of maintenance. Adequate ventilation of the battery shall be provided.

The battery shall provide sufficient power at 48 Volts DC or 110VDC (or any other voltage as indicated on the Contractor's approved shop drawings) to close or trip all the breakers in MV switchgear simultaneously and maintain other loads in the switchgear. Any future breakers shall be taken into consideration when sizing the battery and charger.

The battery shall comprise required number of nickel-cadmium cells at 1.2 Volts / cell with potassium hydroxide electrolyte. Each cell shall be constructed in a semitransparent plastic container. The battery shall have a nominal output voltage of 48 Volts DC or any other voltage as indicated on drawings. The calculations for the capacity of the battery shall be submitted for approval of supervising Engineer. The electrolyte level of all cells shall be visible.

The charger unit shall be automatic constant voltage float / boost type, with solid state electronics employing silicon voltage reference diodes and rated as follows:-

- Input Voltage - 230 Volts, 50 Hz.
- 48 Volts or 110V DC (or as specified in the Schedules and BOQ).
- Charging Current - Adjustable 10% to 105%.
- Stability - Float Voltage $\pm 1\%$; for mains variations $\pm 10\%$.
- Smoothing - Approximately 2% RMS.
- Recharge Float Voltage - 1.44 Volts / Cell.
- Boost Voltage - 1.68 Volts / Cell.

The mains input of the DC battery and charger shall be connected via a suitably rated circuit breaker. Circuit breakers shall also be provided for battery isolation and isolation to the DC distribution panel. An electronic current limit shall be provided at 105% of the rated output current.

A high-low voltage output relay shall provide an alarm when the output voltage falls to 80% or rises to 120%. An AC failure and DC failure alarm shall also be provided. All these alarms shall be provided locally as well as at a remote location, where 24 hour attendance is available as approved by the supervising Engineer.

The meters, switches and indications shall be provided at the front of the charger unit according to NEC. These shall include, but not be limited to, the following:-

- Moving coil DC voltmeter and ammeter for battery.
- A float / boost switch.
- Green neon to indicate that the charger is operating on FLOAT.
- Red neon to indicate that the charger is operating on BOOST.

The battery shall be delivered empty of electrolyte. Sufficient quantities of distilled water and electrolyte in crystalline form shall be delivered for the first filling of the battery

H.32.2.6 Cable Glands

- A. Provide cable glands for the termination of MV XLPE cables at MV switchgear. Cable glands shall provide an adequate, corrosion resistant earth bond for the metallic cable armour together with means of sealing the cable sheath terminations.

The cable glands shall be designed to accommodate MV XLPE cables of all sizes specified under the Contract and main incoming supply cable by EDL or other. The particular option regarding cable dimensions are summarized in the table below:

Cable Size (mm ²)	Diameter underneath the Armour (mm)	Diameter of Armour Wires (mm)
300	70	2.5
240	67	2.3
185,150	64	2.0
50	57	1.6

The cable glands shall allow enough space inside the switchgear cable box to allow cross core connection and easy interchange of phase.

Contact between annour and cable gland shall be ensured by two worm drive clips. This contact should be designed to withstand 21 kA for 3 seconds.

A PVC shroud and stud (M10) shall be provided with the cable gland to connect an earthing cable. Adequate nuts and washers shall be provided as required on site.

H.32.2.7 Accessories

Include as part of the main tender price, all necessary equipment and accessories required to assemble individual units to form complete MV switchgear. These shall include all necessary small wiring, fuses, foundation fixing details, labels, cable termination facilities, sole-plates, busbar interconnections, terminal boards and all necessary sundries.

A wall mounted encapsulated single line schematic diagram showing the operational positions of the unit shall be provided, which shall be black on a white or silver background.

Supply MV switchgear complete with all accessories necessary to form a complete installation including, but not be limited to, the following operation and safety accessories:

- 2 Circuit breaker raise / lower or driving handles.
- 1 set of high voltage test bushings.

- 2 Sets of jumper connections.
- Circuit breaker manual charging handle.
- Set of special tools including circuit breaker trolley for removal and insertion of 20 kV circuit breakers.
- 2 pairs of insulating gloves.
- Notice / safety instructions and first aid chart for electric shock.
- 1 rubber mat 35 mm thick, 1 m wide, extending full length of MV switchgear. The mat shall have corrugated surface with a dielectric strength of 40 kV minimum with 3000 volts to ground.
- Sufficient padlocks with 6 mm shackles having 24 mm clearance.

The supplier shall provide a complete set of drawings for MV switchgear(s) The drawings shall include:

- General arrangement of circuit breaker.
- Schematic diagram for each type of breaker.
- Wiring diagram for each type of breaker.
- Multi-core cable schedules.

Six paper print copies of these drawing sets shall be provided and one complete set of transparency copies.

In English language 6 copies of a combined operating and instruction manual, describing the modes of equipment operation and the necessary on-site maintenance of all items provided. Submission of these manuals should be before shipment of the equipment.

Testing:

- The switchgear equipment and circuit breakers shall receive factory production test as listed below and shall be as per the IEC62271-200 Section 7 Standards: 1. Equipment
 - a. Low frequency dielectric test. b. Grounding of instrument cased. c. Control wiring and device functional test. d. Polarity verification. e. Sequence test. f. Low frequency withstand voltage test on major insulation components. g. Low frequency withstand test on secondary control wiring.
- 2. Operating Mechanism
 - a. Coil check test. b. Clearance and mechanical adjustment. c. 300 Electrical and mechanical operation test. d. Timing test. e. Conductivity of current path test. f. Hi-potential testing of breaker. g. Vacuum bottle integrity test.
- Manufacturer shall provide to the Engineer documents verifying completion of factory production tests.

Finish:

All steel surfaces shall be chemically cleaned and given an iron phosphate corrosion resistant treatment providing a strong bond for paint adhesion. All parts shall be immersed in paint applying 0.7-0.8 mils of cathodic epoxy paint electrically bonded to all surfaces for maximum adhesion. The finish shall be cured in an oven at to insure maximum toughness and prolong service in severe environments.

H.32.3 Execution

H.32.3.1 Inspection

The civil works for foundations must be compatible with equipment and all sizes and details must be as per manufacturer recommendations.

H.32.3.2 Installation

The installation of MV switchgear shall be in accordance with the manufacturer's written instructions and shall comply fully with the requirements of IEC and EDL.

H.32.3.3 Field Quality Control

Field inspection and testing will be performed.

- Dielectric strength or insulation resistance test of completely assembled MV switchgear after installation shall be performed.
- Inspect installed switchgear or anchoring, alignment, grounding and physical damage.
- Check tightness of all accessible electrical connections with a calibrated torque wrench. Minimum acceptable values are specified in manufacturer's instructions.
- Megger and record phase to phase and phase to ground insulation resistance of each bus section. Megger for 1 minute for each measurement at minimum voltage of 1000VDC. Measured insulation resistance shall be at least 1 megohm(s).
- Test each key interlock system for proper functioning.
- Perform tests to prove the operation of all MV circuit breakers, simulate fault on protective relays and devices.
- Current injection test of all protective relays and devices shall be carried out.
- Perform ratio tests and other field tests of all current and voltage transformers.
- Complete functional and trip testing of battery and charger unit including battery discharge test, float and boost charging functions, etc.

H.33. MV MOTORS

H.33.1 General Requirements

This specification covers vertically mounted, 3-phase, squirrel cage, AC induction motors.

- Ambient temperature in a range of -10°C to 50°C
- Maximum altitude of 300 meters above sea level
- Indoor installations
- Use with variable frequency drive (VFD) Standards – All motors shall be in accordance with NEMA standard MG1-2009, or the latest revision in so far as it is applicable or EN 60034 / IEC 34-1.

H.33.2 Electrical Requirements

Voltage and Frequency

- Motors shall operate successfully under running conditions at rated load with variation in the voltage or the frequency not exceeding the following conditions:
 - o +/-10% rated voltage at rated constant volts/hertz ratio except for specific torque boost situations.
 - o Motors shall operate successfully under running conditions at rated load and volts hertz ratio when the voltage unbalance at the motor terminals does not exceed one percent.

Operating Characteristics – with rated volts /hertz ratio applied under standard service conditions, motor performance shall be as follows for critical operating characteristics.

- Torques – Motors shall meet or exceed the minimum locked rotor (starting) and breakdown torques specified in NEMA standard MG1 part 12 for Design B for the rating specified when on sine wave power.
- Currents – locked rotor (starting) currents shall not exceed NEMA Design B values except on motor defined as large machines by NEMA.
- Efficiency – Motor efficiency will be determined according to NEMA standard MG1.
- Part 12, IEEE Test Procedure 112 Method B, using accuracy improvement by segregated loss determination including stray load loss measurements.

Service Factor and Ambient – Standard motors shall be rated for a 1.15 service factor on sine wave power in a 50°C ambient.

Insulation

- Standard medium voltage motors shall utilize Nidec Motor Corporation's Insulife VPI 5000 insulation system which consists of at a minimum Class F or better insulation materials. This utilizes 2VPI cycles of 100% solid epoxy resins completely impregnating slot and end turns. Total of 7 mils of insulation build. This meets NEMA definition of moisture-resistant winding per NEMA MG1-1.27.1

H.33.3 Mechanical Requirements

- Frame size Motors covered by this specification are 449-5812 frame sizes.
- Enclosures
- Motors shall be fan cooled (IP23,IC06) • Material – Motor frame, end shields, fan cover, and inner bearing caps shall be cast iron or heavy gauge fabricated steel construction. • Corro-duty may be specified if all cast iron construction is required.
- Bearings
- Grease lubricated anti-friction ball bearings shall be standard. • Grease lubricated roller bearings are optional, if required due to belted application • Oil lubricated sleeve bearings are optional. • In-service L-10 bearing life of 100,000 hours for direct connected application and 50,000 hours for belted applications.
- Ventilating fans – shall be corrosion resistant, non-sparking material. Some 2-pole and 4 pole motors might have unidirectional fans.
- Conduit box – shall be gasketed between the conduit halves. The conduit box shall be oversize as compared to NEMA type 4 to accommodate large leads or stress cones. Standard box will be cast iron construction, and able to rotate in 90° increments. Larger boxes to accommodate special features will be fabricated steel and not able to rotate.
- External screws and bolts – shall be grade five, hex heads and be plated to resist corrosion
- Motor shaft – 1045 hot rolled steel
- External paint – shall be mill and chemical duty paint, capable of passing a 500 hours salt spray test in accordance with ASTM B117 test method.
- Nameplate – shall be of stainless steel and stamped per NEMA standard MG1 Part 12 and Part 20
- Motor Vibration

Standard and refined vibration per table vibration Level

	Standard	Refined
Number of Poles	Velocity (IPS-Peak)	Velocity (IPS-Peak)
2	0.12	0.09
4	0.12	0.06
6	0.12	0.06
8	0.09	0.06
10	0.08	0.05
12	0.06	0.04

H.33.4 Optional Features

- Conduit Box Special features:
 - Optional features for fabricated steel boxes only
 - o Lighting arrestors
 - o Surge capacitors
 - o Current transformers
 - o Silicon strip type heater
 - o Drain / Breather
 - o IR sight windows
 - o Hinged door
 - Key lock
 - Accessory Conduit Boxes
- NEMA type 4 enclosure to terminate leads of accessories such as space heaters, thermostats, etc. • Cast iron construction
 - o Large boxes will have steel covers
 - o Multiple opening sizes and positions
- Ingress Protection
- Inpro seal – for IP55 ingress protection on drive end bearing and / or the opposite drive end bearing.
 - Grounding Provisions
- Grounding lug available in main conduit box • Shaft grounding ring installed on drive end bracket • Grounding on frame • Grounding pad
 - Insulated bearings – BELZONA type insulation
- Either one or both bearings can be insulated
 - Space heaters – Silicone rubber “strip - type” low -watt, density type space heaters. Space heaters are wrapped around and secured to each end of the winding.
 - Shaft Material – Stainless steel and 4140 high tensile steel
 - Stainless steel hardware
 - Thermal protection
- Bearings – one bearing protective device is available on each end.
 - RTD type – 10ohm copper, 120ohm nickel, 100 ohm platinum, 100 ohm precision platinum
 - Thermocouple – type J, T, E, and K • Windings
 - Thermostats – snap action, bimetallic, temperature actuated switches installed in the connection end-turns of the motor winding. Their purpose is to active a warning. Their purpose is to activate a warning device (N.O) or shut down the motor (N.C) upon excessive winding temperatures. Leads are normally brought out to the main conduit box on 460 volt motors. They are available with normally closed contacts for automatic reset. Overheat protectors with normally open contacts, for use in alarm or warning circuits, are available upon request.
 - Thermistors (embedded in winding) winding thermistors are a nonlinear resistance temperature detector made of semiconductor material and embedded in the end turns of the motor winding, one per phase. They are a PTC type device (Positive temperature coefficient.

- Thermocouples – a thermocouple consists of two dissimilar conductors welded together into a junction. This is inserted into the motor winding – 2 per phase / 6 per motor. Thermocouple leads are brought out to

terminal strip connections in an accessory conduit box, which is included in its price. These accessory signal wires leads are connected to an input instrument (supplied by others) to form a reference junction. Heating of the thermocouple embedded in the winding generates a thermoelectric potential (EMF) proportional to the temperature difference between the two points, indicating the temperature of the embedded thermocouple.

- Resistance temperature detectors (RTDs) an RTD is a sensing element consisting of a precision wound wire coil of pure metal. Recognized for their accuracy, the RTD's resistance increased with temperature rise in a known and highly repeatable manner. Two RTDs per phase 6 per motor are our standard offering. Accessory lead (signal) wires are connected to terminal strip connectors in an accessory conduit box. When connected to an input instrument or monitor (supplied by others), RTD temperature can be monitored.

- Vibration Detectors

• Ability to arrange to accommodate vibration sensor or switch • IEEE 841-Motor will be designed & built in accordance with NEMA MG1 and IEEE 841 Standard. Exception might be taken to sound level exceeding 90 dBA sound power.

H.33.5 Tests

All motors shall be tested to insure correct operation. More extensive testing is available, but is not standard

Common additional testing:

- Short commercial test – this test consists of no-load current, locked rotor current, winding resistance and high potential tests.
- Vibration test – this test consists of vibration measurements (inches / second peak) at three points on the drive end and three points on the opposite drive end in accordance with NEMA MG-1 Part 7.
- Complete initial test – tested per IEEE standard 112, method B, dynamometer test. This test consists of full-load heat run, percent slip, no load current, full load current, locked rotor current, lock rotor torque, breakdown torque (calculated), efficiency and power factor at 100%, 75% and 50% full load, insulation resistance per IEEE Standard 43, winding resistance and high potential. (limited to 700HP for 600 volt ratings and below)
- Sound Test – this a no-load test performed in accordance with ANSI S12.51 and NEMA MG.1

H.33.6 Warranty

Standard warranty on sine wave power for a premium efficient motor is 24 months from date installed or 30 months from manufactured date whichever comes first.

Warranty on VFD power will be 19 months from date installed or 24 months from manufactured data whichever comes first.

Standard warranty on sine wave power for a standard efficient motor is 12 months from date installed or 18 months from manufactured date whichever comes first.

Adjust protective relays and devices to provide adequate over current protection and selective tripping with downstream devices according to short circuit and protection coordination study and after proper co-ordination with protection settings of Electricity Supply Authority EDL.

H.34. Instrumentation

H.34.1 General Requirements

All instruments shall be provided with 24 VDC power supply if applicable. All devices relevant for process shall be supplied by the UPS system.

All equipment shall be protected against aggressive and/or corrosive environment. All instruments shall be installed in the locations shown on the Contractors drawings and where connections are to be made into pipelines, each installation shall be complete with the necessary manifolds, isolating valves, drain valves, test points, sample cocks, etc., as appropriate. Instruments shall be easily accessible for maintenance and calibration. In all cases it shall be possible to isolate and remove the instrument, and fit check gauges, or take samples as appropriate.

All analogue transmitters, receivers and direct wire transmission systems shall have at least a signal level of 0/4 to 20 mA + HART, unless otherwise specified in detailed technical specifications. Profibus and Profinet communication is also possible.

A consistent system shall be installed. The parameterization for each measuring device shall be documented and provided to the Employer in the form of a software file.

All parameter settings shall be stored on a central server system. Parameter settings shall be implemented in change management of the plant.

All measuring transmitters and signal processors, power and signalling lines shall be equipped with overvoltage protection for all; cable inlets shall be watertight and shall fit accurately to the cable size. Transmitters shall be installed together with the overvoltage protection to a mounting pole with protective housing against sunlight and weather. The lifespan and reading of display shall not be disturbed by sunlight.

The distance between the sensor and the transmitter shall be kept as short as possible but with sufficient cable length for easy maintenance of the sensor. Extra lengths of cables if required shall be arranged orderly on cable holders next to measuring transmitters.

The supplies shall include all accessories and materials which are necessary for the correct operation of measurements, adjustments and on site calibration. The overall accuracy of the instruments shall be 1 % of the measuring range.

Measuring devices can be in compact or remote version, with basic or advanced functionalities depending on the measuring point and the importance of the measurement itself for process control.

H.34.1.1 Process Device Management

It shall be possible to configure and parameterize all smart field devices (sensors, actuators, remote I/Os) from the same unique platform, as integrated part of the central Process Control System. It shall be possible to operate and parameterize field devices and components remotely via central parameterization software installed on Engineering or Maintenance station and locally (in the field) via mobile Client (tablet) connected to central parameterization software via local Wi-fi network. All changes made in field devices (remotely or locally) should be automatically centrally stored and updated. It must be possible to define access rights for monitoring and parameterizing. The communication with the devices must be possible with PROFIBUS DP, HART, Modbus, Ethernet and PROFINET. With the software it should be possible to create project-specific field device libraries, to read device parameters and to change, identify and assign field devices, check, read diagnostics and device status data and to simulate device behaviour. Changes to field device data such as parameters, limits and alarm settings must be documented globally and device specific in a user-related Logbook. It shall be possible to assign various roles with defined function privileges to users.

H.34.1.2 Integration of Process Instrumentation in a Process Control System

During equipment selection, preference should be given to devices that have a higher level of integration into the process control system through dedicated and pretested software libraries. This functionality will be considered as an advantage, due to fact that when it is implemented it will increase overall quality of the offered technical solution.

A block library must be made available for main process instrumentation used in a project that enables the integration of these devices into a process control system.

The block library is to be made up of driver blocks, diagnostic blocks and faceplates for the various devices.

The faceplates are used in the operator stations of the process control system as the user interface for the supported process instrumentation, so that the technologically relevant values and functions of these devices can be displayed and operated as objects of that PCS.

The block library is to be provided as engineering and runtime software with a single license for one automation system (one installation).

Bidirectional communication links must be provided on the system side between faceplates and blocks, as well as between blocks and process instrumentation

H.34.2 Installation Approval

Where there is no detail in the Specifications or associated drawings regarding the exact location or method of installation of measuring equipment, sensors, or other site mounted equipment, the Contractor shall submit details of his proposed installation to the Engineer for approval and obtain this approval before starting any installation work.

H.34.3 Cables and Cabling

All cables necessary for the complete installation shall be provided and installed in accordance with the requirements of Section LV switchboards and motor-control gear. All signal and control cables (also for PLC) shall be shielded.

All multi-pair cables, except those connected to remotely controlled actuators, shall include a minimum of 25 % spare cores. This spare capacity shall be over and above any cores that may be required for proposed future installations or extensions. Spare cores in addition to the above may be required in some cables to cater for the spare alarm channels.

There shall be a separate multi-core cable between each motorized valve actuator and the local distribution enclosure or control panel. All such cables shall include a minimum of 2 Nos. spare cores except those associated with actuators having remote control, which shall have a minimum of 12 Nos. cores. All cores, even spare cores, in the cables shall be connected to terminals at both ends.

H.34.4 Instrumentation and Control Equipment Power Supply

All instrumentation, monitoring and control circuits and equipment shall be supplied at a voltage not exceeding 55 volts to earth. These supplies shall be from one of the following:

- A battery / charger unit, typically of 24-volt nominal output, but under no circumstances exceeding 48 volts nominal output;
- A double wound transformer having a fused primary, a 55-0-55 volt secondary with the centre point earthed and each secondary line fused;
- A transformer / rectifier system, comprising a double wound transformer with a fused primary and a secondary having one end earthed, together with a full wave rectifier unit incorporating voltage stabilization if necessary.

The mean voltage of the rectified output shall not exceed the nominal output from the instrumentation battery/charger units. Equipment such as battery/chargers, no break and control power supplies, inverters etc. shall be supplied as necessary to maintain the required electrical supplies to essential instrumentation, monitoring and control systems which are to be kept in operation during a mains power failure. Such essential equipment comprises flow measuring, indicating, recording and integrating equipment or as otherwise detailed in the application clauses.

H.34.5 Field Devices

H.34.5.1 General

Sensors shall be manufactured from durable, corrosion free material, suitable for the installation environment, the local climate and the liquid controlled.

Sensors shall have a minimum protection equal to classes IP 54 or IP 68 (if subject to submersion) and cable or other feed through entry shall not violate the classification.

Sensors shall be connected to a measuring transducer. The transducer shall be equipped with an output of 4 – 20 mA and one adjustable limiting value switch for dry run protection, overflow, etc. This switching contact shall be incorporated into the relay technique of the control.

Supporting steelwork shall be adequate and allow access for maintenance, repair or replacement and shall not hinder the proper functioning of the instrument.

Control units shall be suitable for rack mounting and shall be installed in an appropriate control room. Field control units shall be housed in appropriate field cabinets with a window for control lamps or indicators. The protection class shall be minimum IP 65.

Field cabinets shall have a roof as protection against the elements and a housing in material resistant to strong sunlight or be mounted inside protection hoods protecting the instrument but not reducing the accessibility. The display must be possible to read in strong sunlight as well as at night.

Analogue outputs shall be provided with linear proportionality to the depth range.

When there is demand on local show of measured value, local display shall be included in instrument. Where display for instrument is impossible to see from ground level or platform it shall have an external local display installed. Instrument display and external local display shall be mounted 1,4 m above ground / platform. External local display feed 24 VDC by twin lead, 4-20 mA measure signal.

Delivery of all instruments shall include all necessary mounting details for easy maintenance and accessibility.

All measurement signals, analogue and digital, shall be connected to the process control system.

For flow measuring and analysis (oxygen, pH, redox potential, nitrate, ammonia, suspended solids, ...) there must be a local switch, which will freeze the signals during calibration.

H.34.5.2 Float Switches

Float switches shall be the pendant type with the float suspended on a flexible cable, such that with the float free of the liquid the float and cable hang vertically, but with a rising liquid level the float shall rise and tend to invert.

The float shall be of robust design and comprise a mercury switch having changeover contacts encapsulated in hard plastic foam and connected to a 3 core cable. The whole assembly shall be covered and hermetically sealed in Hypalon or similar material. With the tilting action that occurs on rising level, the contracts shall change over, but there shall be a

dead band between opening one contact and closing the other, during which period both contacts shall be open. This dead band shall operate over an arc approximately 20° either side of the horizontal.

The contacts shall be rated for a minimum of 5 A at 230 V. The voltage on the contacts shall not exceed 55 volts (nominal) to earth.

In all applications the installation shall be complete with approved means of preventing the float (and lead) from movement due to wind or liquid turbulence.

Where float switches are to be used in applications under which they may be submerged during normal operation (e.g. pump control and/or low level alarm); they shall be attached to a weighted chain to minimize movement due to turbulence and also to provide means of raising the units for maintenance and repair. All brackets, fixings, etc. as necessary for the complete installation shall be provided.

The chain / float assembly shall be installed such that the point of suspension is not less than 400 mm from any side wall.

H.34.5.3 Electromagnetic Flow Meters

Electromagnetic flow meters consist of a sensor and transmitter and optionally a cable and a mounting accessories in remote version. They must comply with following requirements:

- Possibility of simple mounting in compact or remote version, supporting easy adoption from compact design to remote and vice versa. This adoption should be possible on site, without dismounting the sensor from the pipe, only by adding / removing a sensor cable and transmitter mounting accessories, during flowmeter installation or later in operation, if requested;
- It must be possible to shorten sensor cables on site during installation;
- Possibility to easily achieve IP 68 protection of sensor at the installation site, after electrical connection of the sensor, using a sealing gel and without compromising the manufacturer's warranty;
- Possibility to verify the flow sensor on site without interrupting the process and removing the sensor from the installation site using a verification tool and with generating a certificate of verification;
- Max. measurement error $\pm 0,4\% \pm 1 \text{ mm} / \text{s}$ (incl. sensor) or $\pm 0,2\% \pm 1 \text{ mm} / \text{s}$ (incl. sensor) if increased accuracy is required at some positions.

Flow meter sensor:

- Lining of material recommended for wastewater;
- Two-way flow measurement (forward, backward, sum);
- Flash memory for storing calibration and verification data and specific user settings;
- Suitable for direct burial and constant work under water;
- with conical design of the inner lining for Improved accuracy at low flows;
- Integrated electrodes for earthing and measuring made of Hastelloy C material, possibility of detecting unfilled pipeline;
- ambient temperature - 40 + 70 °C;
- fluid temperature 0 +70 °C;
- In accordance with PED-97 / 23EG. Flow transmitter:
- Power supply: 115 ... 230 AC + 10 % - 15 %, 50 ... 60 Hz;

- Output signal, 0/4 ... 20 mA + HART, pulse output, status output;
- Max. measurement error: min $\pm 0,4$ % or $\pm 0,2$ % of the measuring range ± 1 mm/s;
- Possibility to replace the transmitter without losing sensor data and the ability to connect one transmitter to different sensors of the same type;
- Housing material: Glass fiber reinforced polyamide;
- Alphanumeric display with keyboard and backlight, 3 x 20 characters to indicate flow values, total values, settings and errors;
- Advanced self-diagnostics for signaling and recording errors;
- Possibility of on-site flow transmitter verification;
- Frequency 0 ... 10 kHz, 50 % duty cycle (unidirectional / bidirectional).
- Time constant 0.1... 30 s, adjustable;
- Degree of protection: IP 67.

The flow meter must be mounted to the pipes, at a location where no turbulent disturbances may cause false results. Mounting material, construction pipes, replacement pipes to install while the sensor is removed, telescopic pipes to ease the removal of the sensor, earthing system, reference electrode system and all electrical connections have to be provided. The measuring transmitter shall be mounted separately so that it can easily be checked and calibrated.

Electromagnetic flow meters shall be preferably used. Other kinds of flow measurement shall only be in-stalled, if electromagnetic flow meters are not applicable (e.g. in open channels, concrete pipes, etc.).

H.34.5.4 Ultrasonic Flow Meter “on pipe”

Ultra-sonic flow measuring equipment for "on-pipe" applications shall operate on the phase difference technique employing 2 No. ultra-sonic probes displaced longitudinally and mounted on opposite sides of the pipe to detect the difference between the upstream and downstream flight times. The equipment shall include acoustic transducers and a transmitter, and shall be installed complete with all necessary fittings, cables and connectors. The acoustic transducers shall be non-intrusive and arranged so that they may be removed without shutting down the process line. All items of equipment attached to the pipe and/or pipe insert shall be of noncorrosive material.

The transmitter shall process the signals from the acoustic transducers and shall:

- provide an output of 0/4-20 mA proportional to flow,
- be suitable for direct or wall mounting with up to 30 m of cable,
- incorporate contacts to initiate an alarm in the event of mal-function,
- include facilities for field checking and zero adjustment.

The complete system shall operate with a minimum accuracy of $\pm 1,5$ % of full scale deflection over the full ambient temperature range. A test certificate shall be provided for each set of equipment.

H.34.5.5 Ultrasonic Flow Meter - Venturi

Ultrasonic flow meters may be used as alternative to electromagnetic flow meters in pipes for flow measurement in open channels, where electromagnetic flow meter as specified above is not suitable. The measurement in open channels shall combine an ultrasonic water level measurement and a flume (Khafagi-venturi or similar).

The ultrasonic level meter should be in remote version with appropriate cable length between sensor and controller.

Controller characteristics:

- Possibility of measuring levels, volume, distance and integrated function for measuring the flow in the open channel with predefined standard profile shapes and the possibility of free configuration of the curve of the dependence of the flow value on the level;
- Level measurement accuracy: ± 1 mm in the range of 3 m;
- Housing material: Polycarbonate;
- Mounting accessories for pipe (vertical and horizontal), wall and DIN rail;
- Integrated local display with backlight and adjustment keys;
- Digital receiver for signal processing from level sensors;
- Advanced diagnostics and level signal processing capabilities:
- possibility to adjust the echo profile of the level - locally (on the display) and using additional software;
- suppression of false echo signals;
- integrated data logger for viewing data on measured values, alarms, daily statistics (min / max / mean flow, daily totalizer, min / max temperature);
- alarm of upper and lower flow limits;
- advanced pump control algorithms;
- sensor submersion detection.
 - One current output: 4 ... 20 mA + HART;
 - Two digital inputs: 0 ... 50 V DC;
 - Three relay outputs:
- SPDT Form C, normally open or closed, 1 A at 250 VAC or 3 A at 30 VDC;
- 2 SPST Form A, normally open, 5 A at 250 VAC or 3 A at 30 VDC;
 - Ambient temperature -20 - +50 °C;
 - Power supply: 100... 230 VAC;
 - Degree of mechanical protection: IP 65.

Ultrasonic sensor characteristics for continuous level measurement:

- Integrated temperature sensor for compensation;
- Temperature: - 20 ° C to + 50 ° C;
- Radiation angle: up to 10°;
- Frequency: 44 kHz
- Degree of protection: IP 68;
- Connection to the processor: using a cable;
- Housing material: weather-resistant plastic.

The components of the Venturi channel have to be delivered and integrated into the concrete structure of the channel during the time of construction. The inlet stretch and outlet stretch have to be according to the manufacturers' specifications as to achieve the accuracy and repeatability certified for cost-accounting purposes. The installed meter shall be resistant against gases, humidity and weathering. The function of the meter should not be affected by these phenomena.

The sensor shall be mounted above the channels' middle to a cantilever that is fixed to poles on both sides of the channel. The distance to the water surface must be more than the sensors block distance. The measuring ultrasonic signal shall not be disturbed by any fittings inside the channel to achieve reliable measurements. The manufacturer shall calibrate the flow meter on site. The Contractor shall submit a certificate stating the accuracy at least at 10 different flow rates within the total range after installation of the flow meter.

All fittings must be easy to access and to remove for maintenance or repair. The scope of supply shall include all mounting material.

H.34.5.6 Hydrostatic Level Meter

Submersible probe for hydrostatic measurement of water levels in tanks and process vessels.

The probe shall have a diameter of not less than 25 mm with a ceramic diaphragm (Al₂O₃ ceramic, 99,6 %) and a stainless steel housing 1.4404 / 316L or 1.4539 / 904 L depending on the type of fluid.

For measuring ranges in accordance with the needs of the application, accuracy class 0,15 % and long-term stability up to 0,15 %.

Degree of protection of the probe is IP 68 according to IEC 60529. with appropriate cable, with integrated moisture filter and FPM seals for use in wastewater.

4 to 20 mA output signal, two-wire system, 10 to 33 VDC power supply.

Terminal box and terminals in accordance with the manufacturer's standard.

For process temperatures from - 10 to + 80 °C. and storage temperatures from - 20 to + 80 °C.

Local display:

- universal digital panel display for process instrumentation;
- easy adjustment and programming with front buttons or separately with software;
- universal input: current (0 / 4-20 mA), voltage, thermocouple and RTD;
- output: 4-20 mA current and 2 relays;
- accuracy 0,1 % full scale;
- power supply: 85 to 256 VAC or 12 to 36 VDC / 12 to 24 VAC with the possibility of powering the transmitter;
- degree of protection IP 65 (front);
- operating temperature from - 40 to + 65 °C.

Mounting and installation should be executed in accordance with the local requirements and conditions. Housing and mounting material shall be made of high grade steel (1.4301).

H.34.5.7 Ultrasonic Level Meter

Depending on the measuring position it is possible to use compact and remote ultrasonic level measurement. Sludge blanket level measurement in settlement tank is also described in particular. Below are the characteristics for all 3 types of devices:

H.34.5.7.1 Compact Design

Ultrasonic level meter with HART version 7. Two-wire device with current 4-20 mA output, powered from a power loop for level and volume or flow measurement applications for liquids or bulk materials.

Easy installation and commissioning with 4 buttons and 5-digit display with bargraph or software.

Measuring range from 0,2 to 12 meters, frequency 54 kHz, accuracy $\pm 0,15 \%$ or 6 mm, resolution ≤ 3 mm, beam angle 10 degrees, operating temperatures from - 40 to + 85 °C. Integrated temperature compensation.

Power supply from 10,5 to 30 VDC, degree of protection IP 66 or IP 68, sensor material ETFE or PVDF copolymer, housing material PBT. EEPROM memory.

Possibility to adjust at least three measurement response speeds (from 0,1 meter per minute to 10 meters per minute).

Possibility to use automatic and dynamic removal of false echo due to known obstructions in buildings.

H.34.5.7.2 Remote Design

Ultrasonic level meter in remote version consists of transmitter and sensor connected by a sensor cable of appropriate length.

Transmitter characteristics

- Ability to measure levels, volume and distance;
- Level measurement accuracy: ± 1 mm + 0,2 % of measuring range;
- Housing material: Polycarbonate;
- Mounting accessories for pipe (vertical and horizontal), wall and DIN rail;
- Integrated local display with backlight and adjustment keys;
- Digital receiver for signal processing from level sensors;
- Advanced diagnostics and level signal processing capabilities:
- Possibility to adjust the echo profile of the level - locally (on the display) and using additional software;
- Suppression of false echo signals;
- Integrated data logger for viewing data on measured values, alarms, daily statistics;
- Alarm of upper and lower level limit values;
- Advanced pump control algorithms (Energy saving algorithms, cyclic pump start,...);
- sensor immersion detection.
- One current output: 4 ... 20 mA + HART;
- Two digital inputs: 0 ... 50 VDC;
- Three relay outputs:
- SPDT Form C, normally open or closed, 1 A at 250 VAC or 3 A at 30 VDC;
- 2 SPST Form A, normally open, 5 A at 250 VAC or 3 A at 30 VDC;
- Ambient temperature - 20 - + 50 °C;
- Power supply: 100... 230 VAC;
- Degree of mechanical protection: IP 65. Ultrasonic level sensor characteristics:
- Integrated temperature sensor for compensation;
- Temperature: - 20 °C to + 50 °C;
- Radiation angle: up to 10°;
- Frequency: 44 kHz
- Degree of protection: IP 68;

- Connection to the processor: using a cable;
- Housing material: weather-resistant plastic.

H.34.5.7.3 Sludge Levels Measurement in Settlement Tanks

Measuring sludge blanket levels in settlement tanks is one of the applications of ultrasonic level meters that has its own specifics. The sensor is completely immersed in water so that the ultrasound wave travels completely through the water. Dedicated mounting accessories must be implemented

Probe for monitoring the level or depth (height from the tank floor or depth of the water surface) of a sludge blanket. The method of measuring the sludge level will be by ultrasonic pulse directed toward the sludge blanket in the tank. The measurement is without contact between the probe and the sludge. The probe defines the sludge blanket based on user-selected sludge concentration or “blanket threshold”. It is equipped with an exchangeable magnetic coupled wiper that cleans the probe. A position sensor that also compensates for angle when the probe is not mounted exactly vertically is placed in the sensor. The probe automatically compensates for temperature. A visual performance LED indicator light indicates proper performance. The probe is factory calibrated. The probe automatically detects deterioration of disrupted sedimentation. It senses the ultrasonic echo return with the information of the separation layer independent of density.

The probe shall be connected to a digital controller.

The system shall include the capability to remotely monitor sensors on any browser-enabled device and present diagnostics on the overall health of the measurements (on predictive diagnostics-enabled sensors), as well as upcoming and required maintenance - reducing user risk and downtime.

Sensor characteristics:

- Measuring principle Ultrasonic measurement;
- Measuring range 0.2 – 12 m sludge level;
- Resolution 0,03 m sludge level;
- Accuracy 0,1 m;
- Operating temperature range 0 – 50 °C;
- Pressure range $\leq 0,3$ bar or ≤ 3 m;
- Power requirements (Voltage) 12 V, 2,4 W, provided by Digital Controller;
- Response time 10 to 1800 s adjustable;
- Flow Max. 3 m/s (the presence of air bubbles affects the measurement);
- Mounting configurations Fixed pole mount, pivot mount or chain mount, depending on application;
- Calibration method One-off on commissioning, automatic;
- Material POM; wiper magnet encapsulating compound: epoxy resin; wiper rubber: silicone rubber. Controller characteristics:
- Display Graphic dot matrix LCD with LED backlighting, transreflective;
- Display size 48 x 68 mm;
- Display resolution 240 x 160 pixels;
- Power requirements (Voltage) 100 – 240 VAC, 24 VDC;
- Power requirements (Hz) 50/60 Hz;
- Operating temperature range - 20 – 60 °C at 0 to 95 % RH non-condensing;

- Storage conditions - 20 – 70 °C;
- Analogue outputs Two (five with optional expansion module) to isolated current outputs, max 550 Ω , accuracy: $\pm 0,1$ % of FS (20 mA) at 25 °C, $\pm 0,5$ % of FS over - 20 °C to 60 °C range;
- Operational mode: measurement or calculated value;
- Analogue output functional mode ;
- Linear, logarithmic, bi-linear, PID;
- Security levels 2 password-protected levels;
- Mounting configurations wall, pole, or panel mounting;
- Enclosure waterproof rating IP 66 / NEMA 4X;
- Conduit openings 1/2“ NPT conduit;
- Relay operational mode: Primary or secondary measurement, calculated value (dual channel only) or timer;
- Relay functions Scheduler (timer), alarm, feeder control, event control, pulse width modulation, frequency control, and warning;
- Relays Four electromechanical SPDT (Form C) contacts, 1200 W, 5 A;
- Communication: HART or Profibus.

H.34.5.8 Radar Level Meter

Radar level measurement shall comply with following requirements:

- Measuring range: up to 15 m;
- Deviation: ± 2 mm;
- Process connection: thread G 1½ A or 1½ NPT;
- Process pressure: -1 ... 3 bar;
- Process temperature: - 40 ... + 80 °C;
- Ambient temperature: - 40 ... +80 °C;
- Operating voltage: 12 ... 30 VDC;
- Casing: stainless steel, PVDF;
- Degree of protection: IP 68;
- Two-wire electronics: 4 ... 20 mA + HART
- Integrated function Dynamic adjustment of the echo curve for false signal suppression during level changes.

H.34.5.9 Pressure Gauges / Manometers

Pressure in pipes, etc. shall be measured and indicated by pressure gauges suitable for the particular duty.

Pressure gauges / manometers shall be of the glycerine filled type and be sealed against the medium to be measured.

Pressure gauges / manometers for fluids and gases shall be of the Bourdon type.

Pressure gauge and pressure receiving cell shall be separated, but interconnected by small-bore coiled pipe.

Pressure gauges / manometers shall be complete with pressure receiver, three-way-valve and tubing all made from suitable stainless steel material.

Mounting and installation should be executed in accordance with the local requirements and conditions.

H.34.5.10 Pressure Measurement

Depending on measuring position and process requirements, it is possible to use two versions of the pressure gauges - basic and advanced pressure gauges.

H.34.5.10.1 Basic Pressure Transmitter

Basic pressure transmitters (also known as cigar or pencil pressure gauges) do not have diagnostic capabilities or adjustment of measuring scale.

The sensor shall comply with following requirements:

- Medium temperature range: - 30 °C ... + 100 °C;
- Piezo-resistant measuring cell made of SSt 1.4016;
- Diaphragm material: SSt;
- Measurement accuracy: $\leq 0,25$ %;
- Permissible overpressure: 300 %;
- Output signal: 0/4...20 mA;
- High grade steel housing: SSt 1.4404;
- Degree of protection: IP 65.

If a local indication and additional functionality in the form of local alarm of limit values is required, then it is necessary to install an appropriate local indicator

H.34.5.10.2 Advanced Pressure Transmitter

Advanced pressure transmitters or “SMART” pressure transmitters have the possibility of advanced diagnostics, change of the measuring range scale, integrated display and buttons for local adjustment, integrated HART protocol and other advanced functionalities.

- Medium temperature range: - 30 °C ... + 100 °C;
- Piezo-resistant measuring cell;
- Diaphragm from SSt;
- Measurement accuracy: $\leq 0,065$ %;
- Scalability of measuring range: 100 : 1;
- Response time: 110 ms;
- Output signal: 4 ... 20 mA + HART 7;
- Housing material: wetted parts made of SSt or other suitable material for selected medium, non wetted parts made of aluminium or manufacturer standard
- Diagnostic functions in accordance with NAMUR recommendations NE107
- Degree of protection: IP 65 or IP 66. Each unit shall be supplied complete with:
 - lines of stainless steel sensors;
 - a local indicator which shall have a separate 3-way-valve (if not incorporated within the transmitter);
 - a test point with separate 3-way-valve;
 - a 3-way-valve for the transmitter. The sensor shall be mounted to a suitable flange fitting with shutoff valve and vent valve. Mounting and installation should be executed in accordance with the local requirements and conditions. The material of the mounting device shall be suitable to the material of the respective tank or pipe. All

fittings must be easy to access and to remove for maintenance or repair. The scope of supply includes all mounting material.

H.34.5.11 Leakage Detection

Leakage detection shall be with intrinsically safe signal circuit for connecting to conductive sensors and shall comply with following requirements:

- Low-cost level limit switch for conductive liquids;
- Line monitoring up to the sensor;
- Configurable sensitivity range;
- Alarm relay can be switched as second level relay;
- Compact housing for simple series mounting on standard rails in cabinets;
- Easy wiring thanks to pluggable terminal blocks;
- Connection to various feed voltages;
- Two-point control and level limit detection.

H.34.5.12 Temperature Measurements

The temperature-measuring unit consists of a sensor and the transmitter. The sensor is mounted to the channel or the pipe with a suitable flanged fitting, whereby the sensor shall be installed within a protective pipe that allows the sensor to be taken out without interruption of the process.

Capillary remote thermometers shall be with a case diameter of preferably 100 mm and must be mounted on fixtures or instrument panels in such a way that they are protected from vibration, jarring and sprayed water. The capillary tube must be laid in a protected position.

Resistance thermometers (Pt-100) in accordance with IEC 751 may be used for measuring the temperature of motor windings, water, brine temperature and similar applications. All resistance thermometers shall be wired according to the four-conductor principle.

Thermometers shall generally be fitted in protective wells. They shall be provided with weatherproof terminal heads and shall be installed so as to totally prevent the ingress of foreign matter.

For all pipework a minimum immersion depth of 55 mm in the internal pipeline cross-section and a minimum distance of 15 mm from the opposite pipe wall must be provided. If the diameter of the pipeline does not allow the thermometer to be inserted perpendicular to the pipe axis while still maintaining the above mentioned distances, another solution must be found in co-operation with the Engineer.

Locally mounted temperature transmitters shall be used for remote indication and functions. Head mounted temperature transmitters may also be used.

The transmitter shall comply with following requirements:

- Output: 0/4...20 mA + HART;
- Field-mounted housing or transmitter in sensor head;
- Degree of protection: IP 65.

If a local indication and additional functionality in the form of local alarm of limit values is required, then it is necessary to install an appropriate local indicator

The service includes installation, all fittings and mounting material. All fittings must be easy to access and to remove for maintenance or repair.

H.34.5.13 pH-Meter

The pH-probe consists of a measuring electrode with membrane glass, a reference electrode and a temperature sensor Pt 100 for temperature compensation and temperature measurement, all combined in one sensor. The sensor body is made of high quality steel resistant to mechanical loads.

The sensor is mounted inside and protected by a high quality steel armature. An adequate measuring transmitter is required with automatic temperature compensation and self-monitoring. The sensor is mounted to the channel or the pipe with a suitable flanged fitting, whereby the sensor shall be installed within a protective pipe that allows the sensor to be taken out without interruption of the process.

The pH-probe shall comply with following requirements:

- Measuring range: pH 1...12;
- Temperature range: - 5 °C...+ 80 °C;
- Permissible pressure: 6 bar;
- Temperature compensation: - 10 °C...+ 55 °C;
- Digital communication with transmitter resistant to interference;
- Min 10 m cable with fast connector. The armature shall comply with following requirements:
- Shaft length according to on site conditions;
- Preamplifier and shielded coaxial connecting cable with watertight and reliable connectors for probe, amplifier and measuring transmitter;
- Submersible armature, self-cleaning, to be lowered into the medium from suitable high grade steel fitting.

The measuring transmitter shall comply with following requirements:

- Display: LCD, range pH 0...14, - 5 °C...+ 80 °C, status-indication, 4 digits;
- Output: 4 x 0/4...20 mA for pH value and temperature;
- Output signal: 1 status contact, potential-free;
- Field-mounted housing;
- Degree of protection: IP 65.

The scope of supply includes one complete spare sensor as well as materials and calibration solutions for two years of operation. All fittings must be easy to access and to remove for calibration, maintenance or repair. The scope of supply includes all mounting material is also included.

H.34.5.14 Oxygen Measuring Device (DO-Meter)

The scope of supply includes the oxygen measurement sensor and a transmitter with all accessories.

Dissolved oxygen measurement shall be carried out by use of oxygen sensitive molecules integrated in a fluorescence layer which is in contact with the medium in combination with an optical sensor.

The transmitter should be a continuously working microprocessor-based O₂-transmitter. An alternative value can be provided to the control system by an extra switch to avoid control errors, if the oxygen measurement is not working due to maintenance or repair.

The probe shall comply with following requirements:

- Automatic zero calibration;
- Self monitoring;
- Construction: Compact probe with cable and plug-in;
- Mechanical fitting: Screw-in thread R1";
- Flow rate: > 0,005 m/s;
- Measuring range: 0-20 mg O₂/l
- Max. permissible temperature: 50 °C;
- Temperature compensation: 0 – 50 °C by two thermistors;M
- Degree of protection: IP 68;
- Accessories for 2 years of operation;
- Digital communication with transmitter resistant to interference;
- Min 10 m cable with fast connector.

The measuring transmitter shall comply with following requirements:

- Automatic calibration;
- Automatic air-pressure compensation;
- Self monitoring;
- Display: LCD, selectable scale, 4 digits;
- Input: Socket for plug-in from the probe;
- Output signals: 0/4...20 mA, 4 status contact, potential-free;
- Field-mounted housing;
- Degree of protection: IP 65;
- High grade steel protective roof.

The sensor shall be fixed to a submerged fitting made of high quality steel that can be lowered into the water from a high grade steel cantilever mounted to the edge of the tank. Before installation the best location shall be determined to achieve a reliable measurement.

All fittings must be easy to access and to remove for calibration, maintenance or repair. The scope of supply includes all mounting material.

H.34.5.15 Turbidity / Suspended Solids Measuring Device

Turbidity / suspended solid measurement shall be carried out by use of self-cleaning measuring probe suitable for measurement in basins or in pipes. The turbidity value is obtained by 90° and 135° scattered light measurement. The probe is connected to a measuring transmitter which is programmable for output in engineering units, i.e. g/l, mg/l, ppm, %, NTU.

The probe shall comply with following requirements:

- Automatic temperature and ambient light compensation;
- Drift compensation;
- Automatic cleaning by mechanical cleaning device (wiper), time interval programmable via transmitter;

- Material: stainless steel (1.4571);
- Admissible temperature: 0 °C.....50 °C;
- Measuring range programmable via the transmitter, adjusted according to the required purpose;
- Linear characteristic;
- Accuracy for turbidity: $\leq \pm 2 \%$ or 0,1 FNU;
- Accuracy for SS: $\leq \pm 5 \%$;
- Digital communication with transmitter resistant to interference;
- Min 10 m cable with fast connector. The measuring transmitter shall comply with following requirements:
- Measuring range: suitable for the required purpose;
- Display: LCD, 4 digits;
- Output signals: 0/4...20 mA, 1 status contact, potential-free;
- 2 user selectable relay contacts;
- Power consumption: Max. 10 VA
- Plug connector to the probe;
- Keypad and alphanumeric LCD display for programming via menus;
- Field housing, degree of protection IP 65.

If used for measurement in basins, the sensor shall be fixed to a submerged fitting made of high quality steel that can be lowered into the medium from a high grade steel cantilever mounted to the edge of the channel. If used for measurement in pipes, the respective fittings have to be included in the offer.

All fittings must be easy to access and to remove for calibration, maintenance or repair. The scope of supply includes all mounting material.

H.34.5.16 Conductivity Measuring Device

Conductivity measurement shall be made by inductive conductivity measurement with integrated temperature sensor Pt100 for automatic temperature compensation.

The conductivity sensor shall comply with following requirements:

- Mechanical fitting: Screw-in thread R1";
- Max. permissible temperature: 90 °C;
- Max. permissible pressure: 16 bar;
- Measuring range: suitable for the required purpose;
- Electrical connection to the transmitter by cable with plug (IP 65);
- Digital communication with transmitter resistant to interference;
- Min 10 m cable with fast connector.

The measuring transmitter shall comply with following requirements:

- Front operation panel;
- LCD-Display;
- Accuracy: $\pm (5 \mu\text{S}/\text{cm} + 0,5\% \text{ of measured value})$;;
- Output signal: 0/4...20 mA, 1 status contact, potential-free;

- Field-mounted housing.

The sensor shall be fixed to a submerged armature of sufficient shaft length made of PVC that can be lowered into the water from a high grade steel cantilever mounted to the edge of the channel.

All fittings must be easy to access and to remove for calibration, maintenance or repair. The scope of supply includes all mounting material.

H.34.5.17 H₂S Measurement

The H₂S measurement system shall ensure a continuous measurement of the H₂S concentration in the atmosphere and the setting of acoustic and optical alarms for selected thresholds. It shall consist of following main components:

- Sensing head;
- Control module;
- Front display panel.

The H₂S measurement system shall provide following features:

- Suitable for field installation;
- Protection class II 1G EEx ia IIC T6;
- Useable in zone 0 area;
- Zero and sensitivity adjustment at the remote sensing head without opening the housing;
- Allow for one man calibration;
- Switch for alarm suppression during one-man calibration and service.
- The H₂S measurement system shall comply with following requirements:
- Designed for various H₂S measuring ranges;
- Minimum two adjustable alarm threshold;
- Permissible ambient temperature: - 10 °C.....+ 55 °C;
- Digital display indicating measured value and threshold values ;
- SPDT contacts for each alarm threshold and failure alarm;
- Min lifetime of the sensor: 24 months;
- Output signal: 0/4...20 mA;
- Approved for use in potentially explosive atmosphere according to Directive 94/9/EC [ATEX 100a], EN 50014 and EN 50020. Class of protection: II 1G EEx ia IIC T6;
- Field-mounted housing;
- Degree of protection: IP 65.

The scope of supply and works includes the complete installation including all accessories, mounting of material and calibration with original test-gas by the manufacturer. A test kit for calibration by the plant personnel also has to be included.

Alarms have to be transmitted to the central control system.

H.34.5.18 Explosive Atmosphere Detector

Explosive atmosphere detectors shall be installed in each building with potential explosive atmospheres. They shall use the principle of infrared light absorption to determine the concentration of explosive gas in the air and set acoustic and optical alarm when the adjustable threshold concentration is reached.

The field sensor shall comply with following requirements:

- Infrared absorption measurement of explosive gases and vapour without moving parts;
- Output signal: 0/4...20 mA;
- Gas access by diffusion;
- Measuring range adjustable:
 - 5...100 % of the explosive limit;
 - 1000 .. 9999 ppm;
 - 1 ... 4,4 Vol %;
- Linearisation adjustable for methane, ethane, propane;
- on-site calibration via alphanumeric display;
- Explosion protection EEXem(ib) d IIB+H2 T4 ;
- Relative humidity: 0...95 %;
- Degree of Protection: IP 65.

The measuring transmitter shall be designed as plug-in card and provide the following functions:

- two adjustable alarm thresholds;
- indication of the actual measuring value;
- 3 potential-free contacts for 1st and 2nd alarm and calibration fault.

Calibration chambers and test-gas with approx. 40 % of the explosive limit methane have to be provides in a sufficient number for the calibration of all delivered units. The scope of supply and works includes non-corrosive mounting material, mounting, adjustment and calibration.

H.34.5.19 Gas-flow Meter

Air and gas flow measurement shall be carried out by vortex low head loss flow meter. The measuring sensor shall either be flanged or flanged between flanges. Flanges shall be PN10 in accordance with EN 1092. Meter body and sensor shall be made of stainless steel suitable for the measured media, i.e. stainless steel grade 1.4571.

A permanent raised arrow shall be marked on the meter body indicating the flow direction.

The flow meter shall be provided complete with amplifier, converter, transmitter and the required connection cables and shall comply with following requirements:

- Output signal: 4...20 mA;
- Protection class: IP 65;
- Maximum pressure losses: < 20-50 mbar;
- Accuracy: minimum ± 1 %;
- Air temperature range: - 50 °C + 100 °C;
- Ambient temperature: 0 °C + 50 °C.

Vibration, temperature and pressure compensation shall be suitable for a maximum air velocity not exceeding 50 m/s.

H.34.5.20 Sampling System for Inlet and Outlet

Automatic sampling systems shall be installed at the inlet and outlet of wastewater treatment plants to collect automatically water samples. Samples shall be taken at locations that guarantee the collection of representative samples. The sampling system shall be installed next to the respective channel on a concrete foundation. It shall be controlled by a microprocessor that allows time-, quantity- or event-controlled sampling sequences. For this purpose, the electrical signal from the respective flow measurement must be transmitted to the sampling system. The instrument is supplied with a vacuum diaphragm pump that sucks water into a dosing chamber. After the pump has been turned off, an adjustable amount of water is filled into a PE bottle by a distribution system that is switched either time based or on the number of samples per bottle. A built-in refrigerator keeps the temperature of the samples at approx. + 4°C (adjustable).

The automatic sampler shall comply with following requirements:

- Lockable high grade steel housing, isolated;
- Weather and sun protection roof, made of high grade steel;
- High grade steel base construction;
- Impulse and analogue signal-input 0/4...20 mA for flow- and volume-proportional sampling;
- Sample collection system with 12 PE bottles, each with a volume of 2 l;
- Cooling of the collected samples, suitable for the local ambient temperature;
- Variable dosing volume 20...200 ml;
- Dosing chamber easily accessible and cleanable;
- Waterproof operating panel and LCD display;
- Output signal, 1 status contact, potential-free.

The scope of supply and works includes the mounting material, the intake and drain pipes and hoses of ample length with a sampling filter of PVC and stainless steel to protect the sampler from being blocked or getting dirty.

H.34.5.21 Online Phosphate Analyser

Analyser with predictive diagnostics for measuring ortho-phosphate in water. The method of measuring phosphate is by molybdovanadate yellow colorimetric method. The analyser performs a zero point calibration automatically without the use of standard solution. Accuracy is maintained by compensating for background colour of the sample at the beginning of every measurement cycle. A self-cleaning process is performed automatically. Capable of measuring as frequently as every 5 minutes. The analyser is equipped with self-diagnostic routines. Includes a humidity sensor to detect leakage and automatically initiate a safe shutdown. Uses a radial piston pump. The analyser requires a universal digital controller.

The analyser has built-in predictive diagnostics capability which increases available operation time. The predictive diagnostics produces alerts for upcoming maintenance tasks by monitoring the instrument's internal components and tracking service requirements. When connected to a properly equipped controller the controller will display status indicators for each sensor with predictive diagnostics capability.

Includes the capability to remotely monitor sensors on any browser-enabled device and present diagnostics on the overall health of the measurements (on predictive diagnostics-enabled sensors), as well as upcoming and required maintenance - reducing user risk and downtime. It includes the capability to connect to a laboratory spectrophotometer to correct process measurements based on lab samples, without having to remove the process sensor from the water.

Technical Data:

- Measurement method Photometric method using vanadate-molybdate;
- Measuring range 0,05 – 15,0 mg/l PO₄-P;
- Detection limit 0,05 mg/l PO₄-P;
- Accuracy $\pm 2\% \pm 0,05$ mg/l;
- Reproducibility $2\% + 0,05$ mg/l;
- Reagent consumption 500 ml/month;
- pH range 5 – 9 pH;
- Pressure range -30 – 50 mbar with continuous sample preparation; at overflow vessel;
- Response time < 5 min;
- Measuring interval 5 – 120 min (fixed values selectable);
- Operating conditions Indoor model: 5 – 40 °C; 95 % relative humidity, non-condensing
- Outdoor model: - 20 – 45 °C; 95 % relative humidity, non-condensing;
- Sample temperature 4 – 45 °C;
- Sample quality: Ultra filtrated or comparable;
- Flow 1 - 20 l/h Sample (free of suspended solids);
- Power requirements (Voltage): 115 or 230 VAC, power provided by the universal controller or a separate power box;
- Power requirements (Hz) 50 Hz.

Sample preparation / filtration system for PO₄-P analyser is mandatory.

Immersed stand-alone sample preparation instrument to continually extract samples directly from process water through ultra-filtration membranes (0,15 µm), with automatic cleaning, and always accessible tubing and 2 alarm relays in case of flow decrease, Multichannel options 1 / 2 channels.

Position includes all necessary mounting equipment and chemicals necessary for work.

H.34.5.22 Online Ammonium Analyser

Analyser with predictive diagnostics for monitoring of NH₄-N and NH₄ in water. The method of measuring is by gas selective electrode (GSE) that uses liquid to gas- phase conversion. The analyser calibrates and cleans itself automatically. Is capable of measuring as frequently as every 5 minutes and is equipped with self-diagnostic routines. Includes a humidity sensor to detect leakage and automatically initiate a safe shutdown. The analyser requires a universal digital controller.

The analyser has built in predictive diagnostics capability which increases available operation time. The predictive diagnostics produces alerts for upcoming maintenance tasks by monitoring the instrument's internal components and tracking service requirements. When connected to a properly equipped controller the controller will display status indicators for each sensor with predictive diagnostics capability.

Includes the capability to remotely monitor sensors on any browser-enabled device and present diagnostics on the overall health of the measurements (on predictive diagnostics-enabled sensors), as well as upcoming and required maintenance - reducing user risk and downtime.

Technical Data:

- Measurement method GSE (Gas Selective Electrode) with screw-on membrane cap;

- Measuring range 0,05 – 20,0 mg/l NH₄-N;
- Detection limit 0,05 mg/l NH₄ – N;
- Accuracy Using standard solutions: 3 % + 0,05 mg/l;
- Reproducibility 2 % + 0,05 mg/l;
- Response time < 5 min;
- Measuring interval 5 – 120 min , adjustable per 5 min;
- pH range 5 - 9 pH;
- Pressure range 30 – 50 mbar with continuous sample preparation; at overflow vessel;
- Operating conditions Indoor model: 5 – 40 °C; 95 % relative humidity, non-condensing;
- Outdoor model: - 20 – 45 °C; 95 % relative humidity, non-condensing;
- Sample temperature 4 – 45 °C;
- Sample temperature Sample quality: Ultra filtrated or comparable
- Flow 1 – 20 l/h sample (free of suspended solids);
- Power requirements (Voltage): 115 or 230 VAC, power provided by the universal controller or a separate power box
- [Power requirements \(Hz\) 50 Hz. Sample preparation/filtration system for NH₄-N analyser is mandatory.](#)

Immersed stand-alone sample preparation instrument to continually extract samples directly from process water through ultra-filtration membranes (0,15 µm), with automatic cleaning, and always accessible tubing and 2 alarm relays in case of flow decrease, Multichannel options 1 / 2 channels

Position includes all necessary mounting equipment and chemicals necessary for work.

H.34.5.23 Online Nitrate Analyser

UV Nitrate Sensor. Process sensor for continuous measurement of nitrate in water. The method of measuring nitrate will be ultraviolet (UV) light absorption below 250 nm. The integrated cleaning system uses wiper technology. It allows the sensor to measure nitrate in media with Suspended Solids contents.

Technical Data:

- Measuring principle UV absorption measurement (unique 2-beam technique);
- Path Length 5 mm;
- Measuring range 1 - 20 mg/l NO₃-N / 5-100 mg/l NO₃;
- Detection limit 1 mg/l NO – N (with standard solutions);
- Accuracy ± 5 % of measured value + 0.5 mg/l (with standard solutions);
- Resolution 0,1 mg/l;
- Sludge Compensation No;
- Measuring interval 5 – 30 min (fixed values selectable);
- Response time 5 min;
- Available with Bypass Yes;
- Material Sensor enclosure: stainless steel 316, 1.4581, single sealed body Wiper axle: stainless steel 1.4571;
- Cable gland: stainless steel 1.4305 Cable gland seal: PVDF;

- Profile carrier: stainless steel 1.4310 Wiper arm: stainless steel 1.4581 Wiper profile: Silicone;
- Measuring window: Suprasil (quartz glass);
- Functional verification Using standard solutions;
- Service interval 6 months or as experience dictates;
- Maintenance requirements 1 hour / month;
- Operating temperature range 2 – 40 °C;
- Pressure range $\leq 0,5$ bar
- Cable length 10 m fixed cable at sensor

H.34.5.24 Analyser Transmitters

To create the optimal configuration and arrangement of analysers in the plant, the use of two types of transmitters is planned depending on the needs at the place of measurement and the specifics of the devices that are located there. The combination of these devices should make the optimal configuration.

Universal Multi-Parameter Controller Modular single or dual channel controller that works with analog sensor modules and/or digital sensors to provide connectivity for over 17 water quality monitoring parameters. Digital sensors give plug-and-play connection capability. Controller should be available with either AC power (100-240 VAC, 50/60 Hz) or 24 VDC power. 4 powered relays with seven options for programming control. Enclosure is IP66/NEMA

4 x rated and can be mounted in a Class 1 Division 2 environment. Option of up to five (5) 0/4-20 mA outputs with programming ability of alarms and seven separate options for programming control. Can be configured with Profibus, or Hart digital communications. Controller is equipped with ability to provide on-screen error and warning messages.

Technical Data:

- Display Graphic dot matrix LCD with LED backlighting, transreflective;
- Display resolution 240 x 160 pixels;
- Power requirements (Voltage) 100 – 240 VAC, 24 VDC;
- Power requirements (Hz) 50/60 Hz
- Operating temperature range - 20 – 60 °C at 0 to 95 % RH non-condensing;
- Storage conditions - 20 – 70 °C
- Analogue outputs Two (five with optional expansion module) to isolated current outputs, max 550 Ω , accuracy: $\pm 0,1$ % of FS (20 mA) at 25 °C, $\pm 0,5$ % of FS over - 20 °C to 60 °C range;
- Operational mode: Measurement or calculated value;
- Analogue output functional mode: Linear, logarithmic, bi-linear, PID;
- Security levels 2 password-protected levels;
- Mounting configurations Wall, pole, or panel mounting;
- Enclosure waterproof rating IP66 / NEMA 4X;
- Conduit openings 1/2“ NPT conduit;
- Relay: Operational mode Primary or secondary measurement, calculated value (dual channel only) or timer;
- Relay functions Scheduler (timer), alarm, feeder control, event control, pulse width modulation, frequency control, and warning;

- Relays Four electromechanical SPDT (Form C) contacts, 1200 W, 5 A;
- Communication: digital HART or Profibus

Advanced Multi-Parameter Controller with predictive diagnostics capability Multi-parameter Advanced controller capable of measuring up to 17 individual water quality parameters. Digital sensors give plug-and-play connection capability. Data output should be available via Profibus DP, GPRS/ GSM wireless communication, or Ethernet/LAN. Controller is 110-240 VAC, 50/60 Hz powered. 4 powered relays with seven options for programming control of the relays. Option of up to twelve (12) 0/4-20 mA outputs with programming ability of alarms and seven separate options for programming control of the outputs. Enclosure is IP65 rated. Utilises display and probe modules. One display module is capable of working with up to four probe modules on the same network. Each network is capable of managing up to 32 sensors. Controller has the option for built in predictive diagnostics capability that increases available operation time of the sensors. The predictive diagnostics produces alerts for upcoming maintenance tasks by monitoring the instrument's internal components and tracking service requirements. When equipped with this option the controller will display status indicators for each sensor with predictive diagnostics capability.

Technical Data:

- Operating temperature range: - 20 – 55 °C / 0 to 95 % relative humidity, non-condensing;
- Storage conditions: - 20 – 70 °C / 0 to 95 % relative humidity, non-condensing;
- Power requirements (Voltage): 100 – 240 VAC, 24 VDC;
- Power requirements (Hz): 50/60 Hz
- Display: ¼ inch VGA graphical backlit TFT colour glass/glass touchscreen, high resistance 320 x 240 pixels;
- Alarm: Low alarm point, low alarm point deadband, high alarm point, high alarm point deadband, off delay, and on delay;
- Relays: Up to four SPDT, user-configurable contacts rated 100 to 230 V AC, 5 Amp resistive maximum per probe module. Additional relays are available with additional probe modules;
- Inputs: Up to 12 analogue 0-20 mA, maximum impedance 500 Ohms per probe module. Additional inputs are available with additional probe modules;
- Outputs: Up to 12 analogue 0/4-20 mA, maximum impedance 500 Ohms per probe module;
- Additional analogue outputs with additional probe modules. Optional digital communications via Modbus (RS485) and Profibus DP/V1;
- Analogue output functional mode PID, high/low phasing, setpoint, deadband, overfeed timer, off delay, on delay;
- Communication : Profibus DP/V1 (certified) ;
- GSM/GPRS Quad-band cellular module (FCC and IC approved, EU and US only) Ethernet service port, RJ45, 10 MB/s;
- Mounting configurations Surface, panel, and pipe (horizontal and vertical) with optional sun shield
- Enclosure waterproof rating: IP 65;
- Material: ABS (display module) and metal (probe module) enclosure with corrosion resistant finish.

H.35. Process Control System

H.35.1 General

The system consists of Automation stations (PLCs for process control) and operator stations for process visualization. The system must support CiR (Configuration in Run) and support online changes. System shall provide high controller performance and capacity with hot swappable-, standard, remote-, intrinsically safe and SIL 2/3 safety inputs/outputs (I/O) where needed. System shall comply to IEC 61508 (up to SIL 3) functional safety for industry. The engineering system shall have a uniform database ensuring that data, which has been entered once by the user, shall be available to all tools throughout the system, thus ensuring that there is a single point of entry for the system database. The system must offer integrated fail-safe features in runtime and engineering. Programming must be based on library of standard, pretested, prebuilt control algorithms for process control with their associated HMI faceplates/symbols including: PID blocks, motor, valve, analogue, digital, alarm blocks. The system shall have blocks specially designed for water industry, including water templates. Integration of main process devices (process instrumentation, VFD, Soft starters, ...) must be supported by standardized libraries to improve control, uniform look and feel, diagnostic and device maintenance.

Plant architecture shall be approved and available as blueprint. The system shall have HMI hierarchy with process object view with automatic generation of faceplates including alarms and trends.

The system shall have Web server expandable with 5 web clients. Web server shall be located between front and back firewall. Web Clients shall not require a full installation of HMI software, but should be operational simply by loading Internet browser over the internet. The System shall allow mobile operation and monitoring with all commercially available mobile devices. No software installation on the end devices is required and the mobile devices have to support simply HTML 5 compatible browsers.

H.35.2 Automation Station Panels

H.35.2.1 General

Prior to ordering equipment and commencement of installation work all relevant drawings, calculations, documents etc. must be approved by the Engineer.

The power supply for PLC and process control equipment in the control room has to be realized by UPS system maintaining the load for a minimum of 2 hours.

All incoming and outgoing cables from the cabinets shall be connected at terminal blocks. All I/O-circuits shall be individually breakable by breakable terminal blocks or fuse terminal blocks. Measuring of signals must be possible from terminal blocks by using miniature banana plugs.

Differential potential durability of galvanic isolation shall be 1,5 kV. All electronic sources in the system shall be able to withstand short-circuiting.

Exi-barrier prevents Exi-circuits voltage to raise over 60 V even in fault situation. Exi-barriers are to be employed in instrumentation and data cabling where cables are going into explosion classified (Ex) area. Ex-circuit connectors and Exi-wiring shall be located separately to own cable conduit inside cabinet and marked by light blue colour.

H.35.2.2 PLC Interconnection

All PLCs of the plant shall be interconnected via a local PLC network. The PLC connection network shall be IP-Ethernet / Profinet based. Inside connections shall be realized using copper network cable whereas outside connections

shall be realized using fibre optical cables only. The status of communication shall be monitored online within the SCADA system.

H.35.2.3 Panel Wiring

Panel wiring shall be carried out using cables installed in a neat, systematic manner, securely fixed and supported on insulated cleats or trunking, and arranged so as not to impede access to any internally mounted equipment.

Analogue signal cables and DC control cables at voltages not exceeding 48 volts (nominal), may be run together in the same cable bunch or trunking; but these cables shall be run separately from all other cables. In any cubicle, panel, or structure which is not fully enclosed (such as some mimic diagram structures), all cabling which is or may be at a voltage in excess of 55 volts (nominal) to earth, shall be run in conduit.

For all cables, the sizing shall be fully adequate for the possible maximum loading, and derating shall be applied as appropriate for cable bunching and ambient temperature.

Terminations shall be restricted to one wire per terminal. Cabling to door mounted equipment shall be protected in flexible cable conduit(s) and created to form a loom with a loop of adequate length to allow easy door opening without causing strain to the components or cable.

Sharp edges of cubicles, trunking, components etc., which may be in contact with cables, shall be protected to avoid damage to cable insulation.

H.35.2.4 Panel Earthing

A copper earthing bar shall be provided and bonded electrically to the main frame. It shall be provided with suitable brass screw terminals for the connection of the metal cladding, instrument frames, gland plates, cable tray, the armouring of all incoming cables and the site earthing system.

H.35.2.5 Indoor Panels

All instrumentation, monitoring and control panels, designed for use within buildings shall be constructed of prime quality, cold rolled and annealed mild steel or zinc coated sheet steel, of adequate thickness welded and braced to form a rigid structure. The minimum sheet steel thickness shall be 1,6 mm, with panel fronts and desktops being thicker (2,00 mm minimum) to provide the necessary strength to prevent buckling. Panel fronts shall be flat and free of bow and ripple. External corners and edges shall be rounded to give a smooth overall appearance. No design involving the use of externally visible assembly bolts or screws will be accepted. All floor-standing enclosures shall be constructed with a 60 mm deep plinth arranged to provide a recessed kicking strip at the front.

Equipment mounting panels shall be not less than 2 mm thick and shall be strengthened and/or braced to avoid any distortion or vibration. Equipment mounting plates and brackets shall if necessary be hinged to provide quick and easy access to equipment securing screws, terminals and wiring.

Doors and access panels shall be adequately braced or strengthened to avoid any buckling or twisting. Doors shall be of folded and welded construction mounted on lift-off hinges, with one hinge engaging before the other. Where necessary, removable access covers secured by quick release fasteners shall be provided. All doors and access panels shall close onto neoprene or soft rubber sealing strips which shall be held in place mechanically and not by adhesive. All doors shall be lockable. Where 'walk -in panels or structures are provided, these shall be fitted with lockable car type handles operable from inside even when locked.

The external colour shall be as approved by the Engineer. The design and construction shall be such as to provide an enclosure of superior quality, which shall match all other panels in the same location in style, appearance and finish, and

have environmental protection to IP 54. In cubicles for PLC (Programmable Logic Controllers) the temperature shall be between + 10 °C and + 30 °C. The relative humidity shall not exceed 85 %.

Each enclosure shall be fitted with one or more heaters to prevent condensation and assist ventilation. The heaters shall be so arranged and located that no deterioration can be caused to any equipment or wiring. The surface temperature of any part that may be accidentally contacted shall not exceed 65 °C. The heating circuit shall be supplied via a fuse, an isolator and an Off/Auto switch. In the 'Off' position the heater shall be isolated and in the 'Auto' position a thermostat or humidistat shall control the heater. All switches and controls shall be mounted within the enclosure.

If required a cubicle AC unit shall be provided. The Contractor shall provide a heat calculation for each cubicle.

H.35.2.6 Outdoor Panels

All instrumentation and control cubicles, kiosks etc. designed for outside use shall be manufactured having walls of double skinned, resin-bonded fibreglass, with a totally encapsulated infill of non-corroding alloy. Box sections shall be encapsulated into door edges and doorframes. Hinges shall be of high tensile, non-corroding alloy with stainless steel pins and through fixing bolts. Large plane surfaces shall have adequate reinforcing to ensure rigidity.

The doors shall be complete with latching handles and locks. All door catches and locks shall latch onto steel reinforced surfaces. The doorsill shall be protected by a non-corroding alloy material. Colour impregnated gel coats backed by coloured resin shall be used to ensure maintenance free and 'colour fast' finishes. The finish colour, both internal and external shall be glossy white. Door-mounted meters and transparent windows shall be of glass, which shall be protected from harmful direct sunshine by orientation or other approved means.

All internal equipment shall be mounted on supports built into the fibreglass structure. Fixing bolts through the skin will not be accepted. Each cubicle shall be constructed to provide environmental protection to IP 55. Each outdoor panel shall be provided with sunshade.

Each enclosure shall be fitted with one or more heaters to prevent condensation and assist ventilation. The heaters shall be so arranged and located that no deterioration can be caused to any equipment or wiring. The surface temperature of any part that may be accidentally contacted shall not exceed 65 °C. The heating circuit shall be supplied via a fuse, an isolator and an Off/Auto switch. In the 'Off' position the heater shall be isolated and in the 'Auto' position a thermostat or humidistat shall control the heater. All switches and controls shall be mounted within the enclosure.

If required a cubicle AC unit shall be provided. The Contractor shall provide a heat calculation for each cubicle.

H.35.2.7 Protection

Overvoltage protection shall be provided for the PLC system.

The measured values shall be protected by surge protectors. The digital inputs / outputs controlled from outside shall also be protected against power surges using relays and opto-couplers. In addition, the power supply shall be protected against voltage surges.

H.35.2.8 Automation Station (Hardware)

All process signals should be acquired by remote I/O peripherals and then transferred to the appropriate main CPU via Profinet. All programming logic and signal processing shall be implemented in CPUs using predefined and pretested function blocks.

Automation stations shall be delivered and mounted completely as a functional package with mounting rack, power supply, CPUs, communication cards, protection devices, circuit breakers, monitoring devices, cables, wires, terminals, fitting materials, etc. including the wiring of the cabinets.

PLCs which come as part of the package units (Screens, CHP, etc) shall be seamlessly integrated in the control system.

Remote I/O peripherals shall have a 30 % spare capacity in the mounting racks for future I/O-modules extensions.

One system clock for time synchronization shall be available for the complete control system

All items shall be supplied as complete and functional units, including delivery, mounting, wiring and connecting. The service includes the technical project planning, preparation and submission of all documentation and their careful storage within the switch gear cabinet.

A clear and suitable arrangement of the panels shall be realized according to the process.

H.35.2.8.1 Central Processing Unit (CPU)

The central controller shall be a modular process automation system with a quantity structure up to max. 100 measuring points / drives (expandable to ≥ 2000). The CPU should be capable of processing standard and fail -safe signals (if needed). The capacity shall be expandable at any time. Controller shall consist of a central processor unit with power supply mounted on steel rack. Each Central unit must have integrated interfaces: 2x PROFINET or for TCP / IP, 1x PROFIBUS interface.

Degree of protection IP 20, ambient temperature 0 – 60 °C.

H.35.2.8.2 Digital Inputs (DI)

Power supply: 24 VDC.

Signals: 16 or 32 ch input module.

LED status display for channel-specific status information and module. Protection against short circuit on the sensor supply. Input delay parametrizable by channel; 0,05 ms to 20 ms. Diagnosis supported channel by channel: Missing load voltage, Short circuit, Wire break.

H.35.2.8.3 Digital Outputs (DO)

- Power supply: 24 VDC.
- Signals: 16 or 32 ch input module.

LED status display for channel-specific status information and module. Protection against short circuit. Diagnosis supported channel by channel: Missing load voltage, Short circuit, Wire break.

H.35.2.8.4 Analogue Inputs (AI)

- Power supply: 24 VDC.
- Signals: 4 or 8 ch (4..20 mA), HART.
- Resolution: 16 bit

LED status display for channel-specific status information and module. Protection against short circuit on the sensor supply. Type/range of measurement parametrizable by channel. Diagnosis supported channel by channel: Missing load voltage, Short circuit, Wire break, overflow, underflow.

H.35.2.8.5 Analogue Outputs (AO)

- Power supply: 24 VDC
- Signals: 2 ch or 4 ch with HART where needed.
- Resolution: 16 bit.

LED status display for channel-specific status information and module. Protection against short circuit on the sensor supply. Output type/range parametrizable by channel. Diagnosis supported by module: Missing load voltage, Short circuit, Wire break, overflow, underflow.

H.35.2.8.6 Communications Processor (CP-PB)

The Communications Processor shall have an electrical interface to connect the CPU and the power line to PROFIBUS up to 12 Mbit/s (45,45 Kbit/s inclusive)

The communication processor and CPU shall allow for programming and configuring via PROFIBUS, cross-network communication between programming devices through PLC routing and module replacement without requiring a programming device.

The communication processor and CPU shall offer following communication services for the PLC:

- PROFIBUS DP (master or slave);
- PLC communication (client, server);
- Open communication (SEND / RECEIVE);
- Extensive diagnostic options are available via PLC programme.

H.35.2.8.7 Communications Processor (CP-IE)

The connection of PLC controllers via communications processors shall permit the direct integration of the controllers into Industrial Ethernet. The communications processors shall have multi-protocol capability and support the following protocols:

- PLC communication;
- open communication (SEND / RECEIVE);
- PROFINET communication;
- IT communication;
- Even connects small applications to Industrial Ethernet.

H.35.2.8.8 Remote I/O

Remote I/O shall be used for acquiring all process signals in the plant. It shall communicate with the main CPU via Profinet. Remote I/O shall support hot-swap functionality. It must be possible to modify one I/O periphery without influencing the rest of the system which can stay undisturbedly in run.

I/O cards shall support extensive channel-specific diagnostics, for example short circuit, wire break, supply voltage, channel fault LED. Diagnostics shall be visualized and available in central control system.

- The remote I/O unit shall comprise Interface module (IM);
- BUS adapter;
- I/O units as specified above.

H.35.2.8.9 Interface Module

Interface module can be installed in safe and also in ex areas zone 2. It shall support media redundancy processing MRP. LED for indicating diagnoses on secondary module errors. It must be possible for Remote periphery to be in RUN with gaps

Module can be exchangeable under power (multiple modules). The remote I/O shall support expansion of up to 64 IO-modules. Interface module shall support failsafe modules, alone, or in combination with non-failsafe modules

H.35.2.9 Human Machine Interface (HMI)

Each cabinet with the main controller shall be equipped with a HMI device (panel PC). HMI devices shall have the same look and feel in terms of visualization and possibility of the same functionalities as the operators on the operator station. It shall be possible to restrict some of the functionalities according to the access rights managed centrally.

HMI device shall additionally ensure:

- 22" touch panel;
- restriction to the programme code;
- monitoring and parameterising functionalities according to access rights.

H.35.2.10 PLC Software

For programming of process objects (I/O signals, motors, valves...) standardized and pretested function blocks shall be used with the standardized visualization. Blocks shall be used, tested and adjusted to water industry. All blocks shall execute in the main CPUs. Visualization pictures shall be generated automatically with the PLC software compilation and shall be uniform.

The scope of works includes the preparation and implementation of the software according to the required amount of data. A memory spare of at least 30 % shall be provided for further software extension. The software and the respective hardware shall be state of the art at time of delivery, of the most advanced technology and optimally tuned to each other.

The correct function of the programmes shall be tested and optimized in all parts of the process while the machinery is working.

The price includes the complete software package, technical clarifications, project planning, programming, testing and generation of the complete documentation, start-up, test run and optimization.

The software shall be delivered on an electronic memory medium (i.e. DVD, memory stick etc.) including implementation and test run on the PLC. The software code shall include all comments. It shall be protected by password protection to prohibit any future changes by third parties.

The software shall include but not be limited to the following features:

- system analysis;
- production detailed instruction lists, functional diagrams, etc. in accordance with the approved system specifications;
- programming of the automation system;
- testing and start-up process of the system including simultaneous operation and integration test;
- all assembly, service and maintenance instructions as well as a hard copy printout of the programme including electronic memory medium.

The programme processing shall be alarm-controlled. Limit values shall be formed (produced, generated) by means of analogue value quantity processing of the corresponding metering data for the switching points of pumps, error messages, etc..

The software must comply with the requirements for the linkage of the SCADA.

Prior to starting with the programming, a duty- specification for the overall system shall be submitted to the Engineer's approval. It shall contain following items:

- functional description of the programme, commenting the programme runs and steps in plain language;

- activation/de-activation of the programme;
- prerequisites for destination-compatible operation (pre-selector switch, release information from other system components);
- generation of “On / Alarm / Failure Messages”;
- alternative strategies in case of failure of the required metering values;
- pre-processing for the data traffic.

The proposed features shall be discussed in all details with the Employer and the Engineer. Results of the discussions shall be included into the duty specification.

Later on, the user shall be able to refer to the revised duty specification as a user manual containing information with respect to possible reasons for failure.

The PLC programme shall be well documented with synonyms used for internal and external signals and bits, and with comments for each rung or network. The synonyms shall correspond with the tag number system of the plant. The complete source code of each PLC under this contract shall be handed over to the client as a softcopy including all required passwords.

As basis for programming, the Contractor shall develop a detailed program description concerning the function of the programmes and the programming structure. The Engineer shall approve this description before the programming work is started.

H.35.2.10.1 Programme Functions

The PLC(s) shall be programmed to prevent start-up of more than one motor at a time as well during start-up of PLC as during normal cyclic operation. The time delay from start of one motor to start of the next motor shall be about 5 sec.

H.35.2.10.2 Alternating and automatic Take Over

Sub programmes for process functions including parallel identical components shall ensure alternating of components once a day and automatic take over in case of faults on one component. E.g. a pumping station with three identical pumps P1, P2 and P3 should operate so that one day P1 is primary pump, P2 is secondary and P3 is the tertiary pump and the next day P2 will be the primary pump, P3 the secondary pump etc. If a fault occurs at P1 or P1 is switched to manual operation, the PLC program shall ignore P1 and substitute it with the P2 etc.

H.35.2.10.3 Automatic Control

Where automatic control is based on analogue values, PID control algorithms shall be used in the PLC. All PID control parameters shall be adjustable from the SCADA. PID controllers should for example control levels in tanks.

H.35.3 Remote Communication

For communication with external parts of the system (e.g. reservoirs, pumping stations, valve chamber, etc.) a state of the art remote communication shall be available. The plant PLC and remote communication system shall be delivered, installed and commissioned by one vendor.

The PLC for remote stations shall include but not be limited to the following requirements:

- Microprocessor based controller to execute program instructions, store data and control data transfer;
- CPU for local operation of the process;
- I/O subsystem for connection of instruments and signals;
- Power supply;

- Redundant communication interface (LTE / GPRS / DSL / static cable connection) and local data buffer up to 4 days;
- Modular expandability of the system;
- UPS system 2 h.

The remote communication shall be based on IEC 60870-5-104 protocol (Ethernet). All data transmission systems have to be secured by use of firewalls and VPN connections. Full access to the remote station by SCADA shall be available.

H.35.4 Service Notebook

An industrial laptop shall be delivered for service technicians. It shall have eighth-generation Intel® Core™ i processor (Coffee Lake) and high-speed RAM (DDR4 RAM). It shall have robust enclosure made of light-weight stable injection-molded magnesium with rubber-protected corners and retractable carry-handle. It shall be used for commissioning, service or maintenance of automation systems, with all commonly used interfaces for industrial applications. It shall be used for service tasks. It can also be connected as client to the central maintenance server station for process instrumentation setting via WLAN. This way service engineer is locally present, but all the changes and settings are executed from central maintenance server and all the changes shall be stored centrally – separate Tablet device can also be used for this functionality.

H.35.5 Process Control System Visualisation

H.35.5.1 Computer System

The Operator Interface consoles use standard PC technology with state-of-the-art hardware based on a Microsoft Windows operating system, and industrial Ethernet communications. PC components are suitably industrialised suitable for control room and process area installation. In The multi-monitor workstation shall allow user configurable layouts. It shall be possible to dedicate monitor to the operator interface. Additionally, it shall be possible to use the other monitor to view other applications without interfering with the viewing of operator process graphics and displays. The operator system and Process control software shall come preinstalled on the workstations.

Primary engineering workstation shall come in 19” format. They are UL -certified and have the CE mark for use in residential, business and commercial environments. They enable high packing density in the control cabinet and save a significant amount of space in the control room due to their low overall height. They have a painted all-metal enclosure which is particularly protected against dust by a filter and pressurized ventilation. This mechanically and electromechanically rugged enclosure has a service-friendly design. They can be installed or positioned horizontally or vertically. This Industrial Workstations are suitable for reliable 24-hour continuous operation. It shall withstand shocks up to 5 g and vibrations up to 0,5 g can be tolerated during operation. It shall provide dust protection through fan-controlled overpressure ventilation across a filter. Replacement of front fan and dust filter without a tool. Card retainers for securing modules, especially for protection against vibration and shock

The Contractor shall deliver, install, connect, programme, test and commission a complete state-of-the-art, at time of delivery, process-control computer system with redundant Server system. This system shall comprise all hardware and software components to fulfil at least all the following requirements:

- It shall receive data from and send data to PLC control systems via an interface unit;
 - the software of the process computer system shall consist mainly of the following blocks:
- complete computer operating software system;
- complete process interfacing and process control software system;

- complete data processing and recording software system;
- complete software system for system generation, maintenance, and data back-up;
- complete software to run the computer network;
- complete interfacing software to run standard data processing PC software like word-processing, database, spreadsheet, presentation, etc. The process viewing computer shall be suitable for use in the control room, shall be equipped with keyboard, mouse, high resolution colour LCD screen and printer and shall have at least following features:
 - adequate Hard disk capacity for data recording for approx. 2 years;
 - English keyboard;
 - track ball or optical mouse with 3 keys;
 - operating system;
 - DVD-RW system;
 - interface for connection to the PLC system, incl. driver software.

The Graphical Plant Display Images (GPI) shall be displayed on a high resolution 27" colour LCD screen with a refresh frequency of at least 100 Hz and at least HD resolution. It shall provide a low radiation, non-reflecting screen surface. The supply shall include the controller card installed in the computer and the connecting cable.

Hard copies and reports shall be printed with a colour printer on paper DIN A3 size. It shall provide a printing speed of approx. 45 pages/minute.

An Uninterrupted Power Supply (UPS) for the Process Control System and for the PLC shall be included in the scope of supply. The duration of power supply after general power failure shall be 120 minutes. The nominal power output of the UPS shall be calculated by the Contractor, the minimum capacity shall be 3 kVA. The system must be equipped with an emergency change-over switching unit (bypass) and a closed battery service life for 10 years without maintenance.

H.35.5.2 Process Control System Visualisation Switchboard

All components of the visualisation system (Server, UPS, Switches, etc) shall be installed in 19" panels. The panels shall be installed within a server room including HVAC system.

H.35.5.3 Industrial Communication

The communication for the plant shall be based on state of the art TCP/IP based communication via copper network and fibre optical cables (FOC). The speed shall be 1 GBit/s.

All network components shall be fully integrated and central manageable by the SCADA software system. All active network devices shall be of the same manufacturer. The following functions shall be available:

- Central management tool;
- Administration of network (LAN, VLAN, WLAN);
- Maintenance tool;
- Reporting function (traffic, etc);
- Diagnostic function.

The communication system shall be high available.

The Contractor shall provide and submit to the Engineer a detailed analysis of the network traffic prior to installation works. After installation and commissioning of the system, the Contractor has to provide a system network analyses report based on measured values.

Switches and Wi-Fi access points used in the network must be designed for industrial environment, with built-in digital inputs for network faults alarming, signalling contacts to alert users of port or power supply failure, redundant power supplies, high speed networking fail-over times of 200 ms or less, extended temperature range - 40 °C to 70 °C. Switches must be tested and released for DCS system.

Network management system shall enable central monitoring and management of industrial networks and topological representation. It shall be possible to fully visualize and monitor networks using SNMP, SSH and HTTPS, PROFINET for diagnostics. It shall support policy-based approach, meaning configuration can take place independently of the type of devices in the network, and regular backups of the device configurations can be made. It shall support central function for a firmware update / upgrade in the network infrastructure, central user administration and documentation inventory. The network diagnosis shall also be seamlessly integrated into higher-level DCS system. NMS also enables configuration of the network infrastructure and topological representation It shall support presentation of statistics of any period, validation of network parameters.

H.35.5.3.1 Firewall

Firewall Functionality:

- Firewall appliance must support configuration of three security zones: external, private and optional (DMZ) Firewall appliance system must support static and dynamic IP addresses (DHCP and PPPoE) on the external interface;
- Firewall appliance has DHCP relay settings that allow the addition of up to three DHCP servers with the ability to perform concurrent communication to up to 3 DHCP servers;
- Firewall appliance can enable DHCPv6 on an external interface;
- Firewall appliance throughput (UDP 1518) must support 49.6 Gbps firewall throughput and 5.2 Gbps UTM throughput (combined GAV and IPS) in full scan;
- Firewall appliance must be a UTM, incorporating URL filtering, IPS, GAV and Application Control;
- Firewall appliance must be a next-generation firewall, incorporating URL filtering, IPS, next-generation antivirus, application control;
- Firewall appliance must support implementation of security policies in application layer (Layer 7), also known as application proxies.

Networking Capabilities:

- Firewall appliance provides the following number of interfaces: Minimum 8*10/100/1000 BaseT interfaces and additionally one 10/100 BaseT; these interfaces should be configured as any of the three types of required security zones;
- Firewall appliance must have a possibility to expand number of interfaces to: Minimum 24*10/100/1000 BaseT interfaces, 16*1000 BaseSX interfaces, 8*10Gb interfaces and 40*10 Gb interfaces;
- Firewall appliance supports multi-wan configurations, at least four external connections to the Internet;
- Firewall appliance interfaces must be able to operate in fail-over mode;
- Firewall appliance supports ability to fail-over to a modem;
- Firewall appliance supports ability to configure modem as an interface for use in WAN failover;

- Firewall appliance supports external interfaces that can operate in round-robin mode and round-robin mode with configurable weights;
- Firewall appliance supports external interfaces and must also function as an "overflow" allowing the use of external links when the capacity of the principal has been exceeded.

H.35.6 Visualization

Operation stations shall consist of:

- Operator stations – visualization of the process, for monitoring and control functions;
- Engineering station - for engineering of automation System (AS) and operator station (OS). The changes can be made online while plant is in the operation. The station shall also have maintenance functionalities in terms of monitoring and diagnostics of smart devices like process instrumentation and peripherals. Diagnostics shall be visualized and available on operator stations and mobile clients (tablets);
- Maintenance station:
 - Network management system – for diagnostics and management of network and industrial network devices. The network diagnostics can be seamlessly integrated into DCS system
 - Energy management system - software for acquiring, processing, archiving and reporting data of energy consumption. System shall have open interfaces for integration into DCS
 - Advanced Long-term archiving, analysis and reporting tool – software for acquisition, display, analysis and documentation of operating data, must be seamlessly integrated into DCS
- Web server expandable with web clients for remote access of client via tablets or PCs with the same look and feel as the operators on the Operating stations and with maintenance functionalities. Remote clients shall be able to access the system via local Wi-Fi network or via Web.

The workstation shall be supplied with a full library of process-oriented objects for the development of process graphics including but not limited to pipes, motors, valves, pumps, tanks, fans, indicators, sensors, and electrical symbols. These objects shall be provided in various formats (static, capable of being dynamically linked to the control strategy, 2-D, and 3-D).

Pre-engineered graphics symbols shall be provided for all process control elements in the standard control library (PID Controller, Valves, Motors, etc.). These pre-engineered symbols shall be designed to call up their associated faceplate and to represent the dynamic behaviours of the underlying control element, without requiring any additional configuration effort. Faceplates shall be generated automatically by the system for each function block / chart provided in the process control library (PID Controller, Motor etc.). Faceplates shall be linked to a corresponding HMI symbol such as a motor or valve. The symbol shall be programmed automatically by the system to call-up the appropriate faceplate without requiring any manual engineering steps. Integration of main process devices (process instrumentation, VFD, Soft starters, ...) must be supported by standardized libraries to improve control, uniform look and feel, diagnostic and device maintenance.

System shall be capable of automatically generating HMI representations of SFCs (aka SFC Visualization) directly from the control strategy, without additional engineering. These screens shall allow operators to monitor the status and interact with an SFC directly from an operator console.

The software consists of the operating software and the application software including all the engineering and programming. All services of the Contractor must be performed in coordination with the Employer and the Engineer.

In addition to the above indicated general requirements, the scope of supply shall include following features and services:

- compilation and submission of a detailed list of all requirements for and the complete functions of the computer system;
- all manuals in English language;
- all data processing and data presentation in English language;
- fully graphical man-machine interface;
- operation via menus;
- password system for special functions;
- clearly defined and completely documented interfacing of all software modules;
- hardware independent software on the basis of standardized operating systems (MS-Windows) with multi-user and multi-task function. This software has to be state of the art at time of delivery;
- possibility to add and connect third-party software by the Employer at any time without compromising the other functions of the software;
- all data to be stored for 6 months in a data base (Open Data Base Connection ODBC/SQL);
- the software system shall be conceived as an open system that may be extended without modifications of the existing software modules;
- data exchange with the PLC-system;
- display of all process data as dynamic graphic plant images, trend curves, etc.;
- extensive and expressive processing of alarm and warning signals with precise and comprehensive messages and suggestions for required actions;
- maintenance, additions or modifications of the software and the recorded process data also via menu-operated software without interruption of the process control or other software tasks;
- operating hour counters for all motors, giving a warning if maintenance intervals are exceeded;
- all process data shall be pre-processed, stored, and recorded in such a way that standard third-party software can be directly applied for further data-processing like: word processing, data-base applications, spreadsheet applications, graphical applications;
- reports have to be generated, displayed at the monitor screens and printed automatically. The data to be printed shall be software selectable;
- selection of analogue data to be sent to external dotted line recorders for continuous recording;
- hardcopy of all monitor displays on the colour printer;
- maintenance software to create, modify, delete and install all data to control the flow of process data and their handling and presentation including creation, etc. of the dynamic graphic plant images;
- processing of analogue values and counter values;
- processing of set points and information;
- processing of commands;
- arithmetic values and logic expressions;
- counter for operating hours and operating cycles;
- manual input of laboratory data;

- process graphics;
- trends;
- reports;
- event log and alarm list;
- archiving and data storage;
- OPC Client;
- Web access for 5 Clients;
- Maintenance System.

The operation of the complete software system shall be easy to learn and to handle by the personnel. All functions shall be menu-selectable, error-safe and self-explanatory.

An automatic backup function shall be installed on the system. Full back up and incremental back up function shall be available. After final completion a full back up has to be provided.

H.35.6.1 Process Data Points

The system licenses shall provide a spare capacity of 20 % in data points for future extension.

Before programming the computer system, the Contractor shall submit complete lists of all process data points that contain all information about the origin of the data, their processing, presentation and their unique identification number.

H.35.6.2 Reports and Long Term Data Storage

This software tool shall be designed for the plant-wide, cross-plant and long-term archiving of operating data as well as its analysis, interpretation and indelible logging. It shall provide the plant operator with excellent support for plant optimization and energy monitoring (according to ISO 50001) and for the fulfilment of reporting obligations.

The following modules shall be included:

- More than 250.000 data points, time-based or change-dependent recording, arithmetic operations, high performance with resolution in the millisecond range, high data security due to TLC (Three Level Cache);
- Data acquisition from any sources and very high data security (even with interrupted connections) and optional time stamp transfer; data transfer from various measuring instruments;
- Interface for printing of reports and logs with input facility for manual laboratory values;
- Presentation and analysis of measured values and statistical values in trends;
- Generation of all required fault and message reports as well as comprehensive statistics;
- Administration module for automatic printing of reports including sending by email.

The following reports shall be produced, shown, previewed at the monitors and printed:

- Daily Report;
- Monthly Report;
- Annual Report;
- Report of all Faults / Alarm report;
- Report of all Status Signals;
- Report of the Maintenance Status of all Units

- Report of Energy demand (according to ISO 50001) The report generating software shall provide all tools to set up reports that are clearly arranged, expressive and explicit. The report function shall provide predefined reports modifiable by the Employer's staff.

If reports are indicated as trend curves, the time interval shall be adjustable from 1 h to 100 days and each part of the curve can be zoomed up to highest scale. For each curve at least 4 measuring signals (e.g. level, flow, current), 3 fixed values (e.g. limit-levels) and explanation texts shall be stored.

The system shall support user defined sets of trends so that commonly viewed historical information can be defined in trends once and easily accessed by selecting a pre-configured screen target incorporated in the graphic display. There should be no practical limit to the number of trends that can be defined.

Each trend screen shall support up to 8 separate pens. Selection of points to be trended shall be menu driven.

Historical trends shall support seamless integration of both real-time and historical data within a single trend window, with seamless movement between the two. In the event that the screen is scrolled to the left, then historical values will be recalled from historical data files. Scrolling the trend far enough to the right will result in current real-time data being displayed as it is collected.

Zoom in/out and moving forwards and backwards in time shall be possible with no more than two operator actions. A mechanism for selecting a location on the trend, such as a hairline cursor and reading the numeric values of the trends at that point in time shall be provided.

It shall be possible to call up new historic trends and configure them online from the Operator Interface. Pre-configured real-time trends shall be available from a faceplate.

H.35.6.3 Graphical Plant Display Images (GPI)

All process data shall be presented symbolically in the form of high resolution graphical images at the monitors. All components of the plant shall be shown in such a way that they can be easily recognized even by inexperienced plant personnel. All displayed data shall be dynamically updated at least once every second, so that the data on a visible GPI are virtually up-to-date at any moment. The time from the selection of a specific GPI until it is fully displayed and updated, should be maximum 1 second. By usage of keyboard or mouse the personnel can choose a particular GPI, scroll and zoom on a specific point of interest. After a specific object is selected by a mouse click, more data about this object are shown and a menu with further commands is displayed. By using this method the motors can be operated, set points can be adjusted, information about the handling of the process data can be programmed and inspected, memos can be inserted by the operating personnel (e.g. to inform other staff members, to remind about faults, experiences etc.). These memos shall appear whenever the specific subject is selected.

Digital process data shall be presented in the following ways:

- as symbols or texts with changing colours;
- as alphanumeric text to appear or change;
- as changes of the display of analogue data (e.g. alarms).

Analogue process data shall be presented in the following ways:

- as numbers with designation of the physical units or %;
- as thermometer-like bars (vertical or horizontal);
- as instruments with moving pointers;
- as freely defined areas (such as filling tanks);

- as changing colours of areas (e.g. exceeding limits);
- as trend curves over the time axis;
- as curves of an analogue value over another value (xy-trend).

For each analogue signal at least two limit values and one hysteresis value can be adjusted.

Alarm and warning signals with precise and comprehensive messages and suggestions for required actions shall be indicated within the actual GPI. For each possible alarm or warning the priority and the need of acknowledgement can be selected.

The GPI shall be programmed and implemented as follows:

- The Contractor shall make himself familiar with the exact functions of the plant;
- The GPI shall be designed by the Contractor after a discussion with the Employer about the general concept of the GPI. Afterwards the Contractor shall present a first proposal of the GPI as a coloured paper print. This proposal shall be discussed with the Employer corrected and a first revision shall be submitted. This process may be repeated until the third revision of the GPI is accepted;
- Then the GPI is installed into the process computer as a first proposal of the final GPI;
- Afterwards 2 revisions may be necessary until the GPI is preliminary accepted by the Employer. After 3 months of continuous operation of the computer by the STP personnel, the GPI shall be submitted for final acceptance. If not accepted, the GPI shall undergo another 2 revisions for correction if the Employer desires further changes;
- The GPI shall be finally handed over as coloured paper prints, as implemented GPI within the computer and on 2 separate storage devices for storage.

H.35.6.3.1 P&I Process Picture

An overview picture based on the general block diagram shall be provided as overview of the plant an initial picture of the SCADA system.

Based on the P&I diagrams of the process design, the SCADA shall provide an adequate number of pictures.

The navigation between the pictures shall be based on a overview / content picture.

H.35.6.3.2 Power Supply Picture

Based on the single line diagramme of the plant a picture of the electrical supply shall be included within SCADA providing the following details:

- Status of Breakers;
- Measuring signals (Voltage, Current, Power);
- Status of supply (public supply, gen sets, CHP, etc.);
- Fault conditions of switchboards.

H.35.6.3.3 PLC Picture

Based on the automation scheme of the plant, a picture of the PLC system shall be included providing the following information:

- Status for each PLC of the plant;
- Communication errors;
- Fault conditions of PLC panels.

H.35.6.3.4 Single Picture for all Electrical Motors

The Single pictures for all electrical motors (pumps, valves etc.) shall include following information:

- Name: e.g. Inlet Pumping 1
- Tag ID: ID Number
- Button: Manual mode - 0 - Auto
- Indicator lamp:
 - Green: Motor ready and running
 - Red: Motor default
 - Yellow: Summary failure indication
- Button: Hours of operation
- Button: Power input / current consumption

H.35.6.3.5 Single Picture for Measurement

The Single pictures for all measurement (flow meter, level meter, physical-chemical parameter, etc.) shall include following information:

- Name: e.g. Level Inlet tank
- Tag ID: ID-number
- Button: measured value [m]
- Button: limit value MIN MIN [m]
- Button: limit value MIN [m]
- Button: limit value MAX [m]
- Button: limit value MAX MAX [m]
- Button: limit value for start pump (adjustable)
- Button: limit value for stop pump (adjustable)

H.35.6.3.6 Curves

The SCADA System shall provide for the possibility to visualise at least 5 curves each in individual colours in the same picture. It should be possible to generate stable curve images, which among other things should be obtainable for viewing through the menu, function keys or by indicating the curve name or number. Moreover it should be possible for operators to generate additional curve images.

On the curves should be indicated scaling, units, y-axes and tag number and description in the same colour as the curve. It should be possible to get values for a curve from the historical database of the system or historical data stored in archive files. Both historical and dynamical curve images should be shown. In dynamic curve images, new collected / stored data should be added.

Curve images shall be shown on the basis of a combination of historical and dynamic data. Zoom functions in x- and y-axe direction shall be available. Zoom in and out on x-axis in resolution from 100 % to 2 % of the period. Zoom in and out on y-axis in some pictures shall be possible within the spot's scale area. Scaling shall be freely selectable (independent of process signal scaling).

It shall be possible to activate a line of sight, where time connected values are indicated. Time and process values shall be shown on the curve image and in the print out. Line of sight shall be freely movable along the x-axis direction.

Plotting of a curve image shall be possible by activation of a function key. Curve plot shall be in full graphic quality.

H.35.6.4 Alarm Management

Alarm management on the computer screen shall be carried out as follows:

- Alarms shall be registered in the main station computer within 5 sec;
- Alarms shall be saved in a queue sorted according to priority and time of event;
- It must be possible to acknowledge alarms via a component or alarm list;
- It must be possible to acknowledge alarms individually or in groups;
- Acknowledged alarms shall disappear from the alarm line and shall be transferred to the alarm list. Alarms shall remain in the alarm list, until they are deactivated (corrected);
- Alarms shall be shown in the graphical process image. Alarms shall be provided with alarm identification, e.g. first in enlarged part image of the process image;
- Alarm list shall be updated dynamically and update time must not exceed 10 sec;
- It shall be possible to assign priorities to all alarms according to the supervision agreement. It shall be provisioned that alarms are split up in up to 3 priorities. It shall be possible to freely change alarm priorities from the computer screen.

Following data shall be saved in the alarm database:

- Time of alarm occurrence in whole sec., day, month and year;
- Level;
- TAG No;
- Description of component;
- Alarm text or fault message text of at least 30 characters;
- Time of acknowledgement;
- Identification of operator who acknowledged the alarm;
- Time of out-going alarm.

Content of the alarm list (on screen or in print) shall be freely selectable between the information in the alarm database. Sorting criteria for alarm list shall be freely definable by the operator.

It shall be possible to change alarm settings for measurements under normal operation. It must be provisioned that after acknowledgement of the alarm, process image objects can change colour and flash red. Standing acknowledged alarms shall flash red, until the fault is corrected.

Alarms shall be reported immediately even during running of other functions such as print out / generation of reports etc.

It shall be possible to lock (suppress) and release pending alarms. Alarm list shall state time of locking and releasing of alarms. When the alarm is locked, it shall be shown as standing but acknowledged, e.g. by changing to a different colour.

In general, it shall be possible to define whether the alarms which are not acknowledged shall be registered in the alarm database with a new time of "in" and "out", or if a new registration shall take place only after acknowledgement of alarms.

At acknowledgement of alarms time and operator name shall be registered in the SCADA database. Passing alarms must also be acknowledged. Alarm status shall appear clearly from the alarm list e.g. by change of colour of unacknowledged alarms.

H.35.6.5 Data Storage and Retrieval

All data shall be stored together with time stamps in the archives on the hard disks of the main process computers. The databank can be searched with software filters in order to collect specific information about particular dates, machines, faults, conditions and so on.

The data shall be treated as per regulation. This means they have to be gathered every 1 minute and stored for 36 days. The data shall then be compressed to:

- 5 minute intervals stored for 10 days;
- 15 minute intervals stored for 35 days;
- 30 minute intervals stored for 100 days;
- 60 minute intervals stored for 400 days;
- daily intervals stored for 1825 days;
- monthly intervals stored for 240 months;
- yearly intervals stored for 25 years.

H.35.6.6 Alarm, Events and Messages

The alarm system shall provide complete alarm and event management with a user definable message structure. The alarm system shall support definition of up to 16 message sub-classes and 16 message types. Alarm messages shall be time-stamped in the controller. The alarm system shall record any change of state that the system detects including:

- Any violation of limits;
- Any change of state of a device connected to the system including all of its peripherals;
- The failure of any communications channel used by the system;
- The failure of system's hardware, which results in an automatic fail - over of the system's functions from the active to standby device.

The alarm system shall display alarm messages in a manner to facilitate easy interpretation of the current alarm status including but not limited to:

- Different text colour and background colour for those points that are in alarm, those that have been acknowledged, and those that are no longer in alarm;
- Flashing of the current alarm message(s) in the alarm list. It shall be possible to manually inhibit alarms on a point-by-point, group or system-wide basis. This capability shall be protected by system access control. These actions shall be logged. A list of suppressed alarms shall be available at the operator station.

Alarms are classified into 2 categories:

- Process alarms are generated from changing alarm attributes of process I/O point or any calculated point;
- System alarms generated from failures of individual system components shall result in the generation of an alarm message.

All alarms shall be stored in the history files with the capability to archive these to removable media. The system shall provide the possibility to recall these alarms in visible display lists and printed lists according to selectable filtering options.

The alarm management system shall offer the possibility to send error messages fully automatically to a variety of possible recipients in a variety of ways:

- Android smart phones with ACC-App via SMS, Internet and WLAN;
- iPhones with ACC app via Internet;
- SMS on cell phones;
- text messages to Ascom and Funktel pagers;
- voice output on telephones via ISDN and VoIP;
- text messages and voice output on telephones;
- email to suitable receivers.

The alarm management system shall offer following functions:

- integrated shift and personnel management for time-dependent delivery of messages to different persons;
- comprehensive escalation system for reliable delivery of messages even if individual receivers cannot be reached;
- redundancy for fault-tolerant systems;
- alarm filter for suppressing message bursts, follow-on messages, and chatter messages;
- system monitoring for monitoring alerting functions by means of cyclic hardware and software component testing;
- logging of changes to the configuration such as deletion of a telephone number or reorganizing the call sequence.

H.35.6.7 Process History

For the long-term archiving process history shall be used. It is a fully integrated archiving system to manage historical data with capabilities to support the following is required:

- Archiving of process values, messages;
- Post-processing (mean value, maximum / minimum value, rate of change, data compression, filtering);
- Query and visualization.

The system must be able to capture data according to a specific project configuration. It must also be able to respond to data request requests in a timely manner, without interfering with data collection or otherwise compromising performance.

The system shall provide the ability to select, add to and configure for archiving any variable in the process automation system. Variables that are configured or modified in the process automation system must be automatically displayed in the system for historical data management without additional configuration.

Users must be able to access data without the need for process automation system expertise or anyone else.

The historical data management system shall include the following two archiving systems:

- Short-term archiving: A local component that runs on the HMI server to record data from the process control system;
- Long-term archiving or the history: The long-term archiving system is executed on a dedicated machine and archives the data of the short-term archive for a longer period of time.

The long-term archiving system must use a relational Microsoft SQL database management system (RDBMS) in real time to store all process-relevant information.

The long-term archiving system must manage all activities to ensure continuous access to archive data as long as needed. The long-term archiving system can be connected via an interface with higher-level systems (e.g. MES) as well as with other systems that require process automation system data.

Under no circumstances it shall be possible for users to gain data access to the process automation system data network, server or automation system, etc., via the long-term archiving system.

The HMI can display data from the short- and long-term archiving system in different ways, such as trends and tables:

No data loss: if a connection is lost between the history and the HMI Server, the data is continuously stored and secured on the HMI Server (local storage and transfer principle). Once the connection is restored, all missing data is automatically transferred from the HMI server to the history.

The history shall have a function for archiving values including, but not limited to the following values:

- Actual value;
- Maximum value;
- Minimum value,
- Sum;
- Average.

The history must provide the ability to archive binary values on either a rising or falling edge.

Backup/restore of the history database:

The system shall provide functionalities for backup/restore of the database to removable storage media or to an alternative storage location. The Backup Utility shall be able to perform database backups based on any of the following configurable criteria:

- Manual creation of complete database backups;
- Automatic creation of complete database backups.

The restore function must be able to create the database in the same paths as the original database.

H.36. Safety Equipment

H.36.1 Fire Alarm System

A fire alarm system should be installed at all rooms where flammable material is handled or stored especially at the diesel generating station, all fuel tank rooms, biogas storage and biogas handling rooms, storage rooms for fuel, paint, solvent or other flammable material. The administration building and workshops shall also be protected by the fire alarm system.

It shall consist of a central fire alarm unit, a sufficient number of smoke and heat detectors in all endangered rooms, manual fire alarm boxes, optical and acoustic alarm devices, complete cabling and any further equipment to realize a complete and functioning fire alarm system according to EN 54, DIN 14675, VDE 0833 and the relevant local standards.

The cabling shall be carried out with signal cables, conductors at least 0,8 mm diameter, marked red along the entire length. The service also includes software, programming, adjustments, installation, configuration, tests, mounting and mounting material.

H.36.1.1 Central Fire Alarm Unit

The unit has to meet all relevant international and local standards and must be suitable for the connection of automatic and manual alarm devices and shall comply with following specifications:

- power supply: 230 VAC, 50 Hz;
- operating voltage: 12 V;
- emergency power supply: 2 x 24 hours, with lead-acid-battery;
- degree of protection: IP 30;
- installation in a wall mounted cabinet
- front surface with keyboard, lighted LCD display (2 lines) for indication of status, alarm counting, date, time, etc.;
- free programmable additional texts to be assigned to single events or detectors;
- self-diagnosis and acoustic alarm for internal faults;
- cyclical polling of all detectors (approx. every 0,5 second);
- multiple polling with noise suppression by plausibility check;
- overvoltage protection for all detector line inputs;
- output contact for each detector line status;
- output contacts for alarm and faults;
- switching of detector lines via the keyboard;
- easy revision for all detector lines;
- sufficient interfaces for connection of remote control panel, indicating panels, printer, etc.

In addition to the optical and acoustic indication as specified below, alarms have to be transmitted to the central control system.

H.36.1.2 Manual Break Glass Points

Manual Break Glasses shall be installed next to each Emergency Exit They shall be red coloured, for installation in dry rooms according to DIN 14675 and provide the following features:

- integrated evaluation logic;
- programmable address;
- red plastic housing (colour RAL 3000);
- wall mounting;
- Labelling "Fire Alarm" in English and local language
- 5 mm LED for release indication;
- ambient temperature: - 30 ... + 70 °C.

H.36.1.3 Fire Detectors

Fire detectors shall be multiple-type smoke and heat detectors of the scattered-light-, ionization- and temperature-difference-type with integrated evaluation logic. They shall have following characteristics:

- locating primary and secondary alarms;
- locating faulty or dirty detectors;
- infinitely variable adjustment of ambient conditions;
- automatic sensitivity control;
- signal analysis by combination of sensors;
- reproducible detection for all kinds of fire;
- status indication by LED.

The service includes the complete installation with socket, cable connection, adjustment, mounting and all required material.

For areas with restricted access (transformer rooms, height of room > 6 m) smoke aspiration systems shall be installed to enable maintenance.

H.36.1.4 Alarm Devices

Indoor and Outdoor alarm devices have to be installed at each access door to the buildings and shall have following characteristics:

- Outdoor:
 - Flash light;
 - Acoustic alarm.
- Indoor:
 - Flash light (for pump room and gen set room only);
 - Acoustic alarm.

Acoustic alarm horns shall comply with DIN 33404, part 1, and provide following features:

- programmable steady or changing tone;
- sound level: approx. 100 dB(A) at 1 m;
- degree of protection: IP 42;
- red plastic housing.

In addition a siren with red flashing light has to be used for optical and visible signalisation at the outside of each protected building. It must be suitable for outdoor installation (IP 66).

H.36.2 Gas Detection System

The Gas detection system shall measure and display the gas concentration and shall provide audio and visual alarms when pre-set limits are exceeded. Relay output for alarms and malfunction indications and analogue signal representing gas concentrations shall be provided.

The system shall be configured for fail-safe operation. Failure of a sensor shall generate an alarm. The system shall consist of a sensor, control module, and calibration check kit including sensor separation accessories and calibration gas tanks. Alternatively 24 VDC loop powered gas detectors with 4-20 mA output are also acceptable. Sensor and transmitter location shall be as required in the fire protection and security concept.

The gas detection system shall operate from 24 VDC power supply, which shall be battery backed for a minimum of 48 hours. The electrochemical sensors shall have a minimum operational life of one year. Gas concentration signals and malfunction alarms shall be interfaced with the RTU for remote monitoring.

The control module shall amplify the sensor current signal through a solid-state amplifier for display and alarm functions. The control module shall include a two or three-digit led display per channel. It shall also provide a minimum of three digital alarm outputs: low, high, malfunction and an analogue 4-20 mA output signal per channel.

Gas detectors should be located as close to potential leak or gas generation points as possible. The presence and concentrations of gases that must be detected should be considered with respect to the following conditions when designing gas detection installations:

- Air currents: Detectors should be positioned where prevailing air currents contain the fullest possible concentrations of gas;
- Relative weight of gas: Detectors should be located near the floor for heavier-than-air gases or vapours, and near the ceiling or roof to detect lighter-than-air gases such as methane and natural gas. Vapours from all liquids are heavier than air;
- Heat: Standard diffusion type detectors are designed to operate within a specific ambient temperature range and must not be located outside this range;
- Water, moisture, dust and dirt: Detectors should be positioned where water cannot enter and fill the housing to prevent exposure of the sensor element to air. Likewise, exposure to moisture, dust and dirt should be minimised by locating detectors away from points where large amounts of such contaminants fill the air. Small overhanging or surrounding covers may be devised to protect detectors from the intrusions of dust and dirt in severe environments; Permanent installations shall initiate safety systems such as ventilation fans etc., when high concentration of hazardous gas is detected.

H.36.3 Intrusion Alarm System

A burglar alarm system shall be installed at all rooms with doors or windows to the outside of the administration building.

It shall consist of a central burglar alarm unit and a sufficient number of motion detectors, plunger contacts and magnetic contacts in all endangered rooms, optical and acoustic signaling devices, complete cabling and any further equipment to realize a complete and functioning intrusion alarm system according to the relevant local standards.

The service also includes software, programming, adjustments, installation, configuration, and tests, mounting and mounting material.

Central Intrusion Alarm Unit The unit shall meet all relevant VdS, DIN, VDE and local standards and must be suitable for the connection of automatic and manual alarm devices. It shall provide the following characteristics:

- power supply: 230 VAC, 50 Hz;
- emergency power supply: 2 x 24 hours, with lead-acid-battery;
- degree of protection: IP 30;
- installation in a wall mounted cabinet;
- front surface with keyboard, lighted LCD display (2 lines) for indication of status, alarm counting, date, time, etc.;
- free programmable additional texts to be assigned to single events or detectors;
- self-diagnosis and acoustic alarm for internal faults;

- multiple polling with noise suppression by plausibility check;
- overvoltage protection for all detector line inputs;
- output contacts for alarm and faults;
- switching of detector lines via the keyboard;
- easy revision for all detector lines;
- sufficient interfaces for connection of remote control panel, indicating panels, printer, etc. In addition to the optical and acoustic indication as specified below, alarms have to be transmitted to the central control system and must be indicated and processed as any other fault of the plant.

Motion Detectors Infrared motion detector shall comply with VdS Class: B and VdS No.: G 101514.

The infrared motion detector is used to monitor interior spaces. Using optical mirrors it detects infrared heat rays, in wave lengths emitted by the human body.

The new TRAP technology (Threshold Regulated Algorithm with Power-management) offers excellent protection against false alarms and outstanding detection characteristics. Alarm criteria are distinguished very efficiently from false alarms. Simultaneously energy consumption is kept to a minimum.

The motion detector is designed for connection to intrusion alarm central units with detectorbus and shall have following characteristics:

- Detection range 15 m;
- Power supply: 9 – 15 VDC;
- Quiescent current take up idle approx: 0,9 mA;
- Current take up each LED approx.: 10,9 mA;

The service includes the complete installation with socket, cable connection, adjustment, mounting and all required material.

Plunger Contact Plunger contact shall comply with VdS Class: C and VdS No.: G 100023.

Plunger contact shall be of dust and waterproof design (IP 67) with integrated cable. The plunger contact is used to monitor that doors are closed. It consists of a micro-switch installed in an aluminium housing with lever mechanism. The plunger contact is built into the lock plate and activated by the lock bolt. The switching point can be set via a screw as a function of the bolt travel.

Plunger contacts shall comply with following characteristics:

- Index of protection: IP 67
- Loading capacity of the contacts: max. 30 VDC / 100 mA. The service includes the complete installation with socket, cable connection, adjustment, mounting and all required material.

Magnetic Contact Magnetic contact in Set with surface housing according to VdS Class: B and VdS No.: G 104511

The magnetic contact monitors the opening of doors, windows, junctions, etc. It consists of a reed switch in a cylindrical plastic housing and a permanent bar magnet. For surface mounting this set includes 2 surface mounting housings and 2 spacer blocks each of 2,5 mm and 5 mm.

Magnetic contacts shall comply with following characteristics:

- Connection cable: 4 x 0,14 mm² with equal coloured wires;

- Connection cable for LSA-Plus-technic;
- Cable diameter: 4 mm;
- Loading capacity of the contacts: 30 V / 0,1 A;
- Index of protection: IP 68;
- Operating temperature: - 25 to + 60 °C.

The service includes the complete installation with socket, cable connection, adjustment, mounting and all required material.

HF Reader HF reader according to VdS Class: C

The HF reader units are designed for connection to the intruder alarm systems with an interface. The operating status is shown directly at the reader unit by means of dual LED and piezo-electric sound emitters. With the combi-reader units an AND/OR association between identification chips is always possible.

In-wall assembly kits are available for flush mounting, consisting of a plaster box, mounting frame and cover. Activation of the HF reader is performed without contact via an authorised HF transponder.

HF Reader shall comply with following characteristics:

- Connection cable: 4 m;
- Environment protection category approved to VdS 2110: Class IV. This includes a reasonable amount of HF key transponders for the staff.

The identification chips have a permanently programmed authorisation memory for identification by the intruder alarm systems with interfaces.

Each identification chip has its own unique code derived from 10 million possible combinations.

The HF key transponder does not require its own energy supply and can thus be used at any time. Information is transferred to the HF reader unit without contact. This type is particularly suitable for marking with an incremental number. For this, the transponder is provided with a circular area with a white background.

The service includes the complete installation with socket, cable connection, adjustment, mounting and all required material.

Signalling devices For indoor mounting at the administration building, acoustic alarm horns according to DIN 33404, part 1, have to be supplied, providing the following features:

- programmable steady or changing tone;
- sound level: approx. 100 dB(A) at 1 m;
- degree of protection: IP 42;
- red plastic housing.

In addition a siren with red flashing light shall be used for optical and visible signalling at the outside of each protected building. It must be suitable for outdoor installation (IP 66).

H.36.4 CCTV System

The Contractor shall supply, install, test & commission a state of the art digital TCP/IP-based CCTV monitoring system. The system should be a stand-alone system that is capable of being linked to a site wide system. A typical CCTV system

for a building should comprise of colour cameras, lenses, monitors, pan & tilt units, time lapse VCRs and all necessary cables & accessories for a fully functional system.

The CCTV System shall be state of the art (HD) and compliant with best latest practices and local regulations. All installed cameras shall be Pan/Tilt/Zoom (PTZ) type to ensure full coverage of all locations. In areas of high risk of gas, such as the sludge treatment facilities, ex-proof camera and cable installations shall be included.

The system shall cover the complete fence of the plant as well as all entrances

The system shall be located in the Control room and should be integrated. The system should be comprised of the following components:

- HD resolution IP cameras;
- HD DOME IP cameras for outside, infrared sensitive;
- LED infrared emitters for outside installations;
- Pan, Tilt & Zoom controllers;
- Video Monitors, Plasma Screens or Video Walls;
- Video storage;
- Interfaces to SCADA installations. The following functions shall be provided by the system:
- motion detection;
- automatic sampling with event trigger;
- comprehensive software; The CCTV system shall be connected using a TCP/IP based network. Copper cables (CAT7) shall be used for internal installation up to 90 m. For outside installations or longer distances fibre optical cable shall be installed.

H.36.5 Access Control

The Contractor shall design and deliver a state of the art access control system for the plant and corresponding structures. The system shall be software based and easy to handle.

The system comprises RFID access devices (cards or chips), electronic locks with user interface for all entrances and the central management software station. It must be possible for each single access device to manage the access rights to the different zones of the plant by software. Even in case of a lost device, the card can easily be disabled. The user interface at the doors shall give direct response to the user e.g. by green/red lights and/or sound.

The central management station shall be provided with server hardware and shall be installed in the central control room of the plant. The system shall be expandable and built for management of unlimited number of users.

The system shall be TCP/IP based with wireless LAN access points. The following doors shall be equipped as a minimum requirement:

- main plant access / gate;
- entrance doors to all buildings;
- control rooms;
- offices;
- switchgear rooms;
- technical rooms;

- laboratories.

H.37. Test and Approval Procedure

H.37.1 General

The Contractor shall request inspection and testing of all items of plant, mechanical and electrical works and shall give the Engineer four (4) weeks' notice that the equipment is ready for testing and of his intention to carry out tests in accordance with Contract provisions.

If any of the tests are beyond the resources of the Contractor or the Manufacturer, the Contractor shall make arrangements for these to be carried out elsewhere on suitable testing facilities.

The Contractor shall carry out tests as stated in the applicable National or International Standards (EN, ISO or IEC), for performance tests and such other tests that are stated and as may be deemed necessary by the Engineer, to prove that the Works comply with the Specifications set forth by the Contract Document as a whole. Each test certificate shall be in accordance with the Contract provisions, and shall contain concise information of the test; e.g. (Contract number and details, pay item number, prevailing specifications, manufacturer, type, model, serial number etc.) for unambiguous identification of the material or equipment tested and the extent of the certificate's validity.

The Contractor shall be responsible to fully document all tests carried out and readings taken and to keep a neat record of all tests.

However, no inspection, release or approval of any part of the Works by the Engineer, shall release the Contractor from any of his obligations under the Contract.

Whenever tests and inspections have been completed to the Engineer's satisfaction and when the test certificates, (including reports, notes, tables, graphical representations of results etc. as technical annexes) have been checked and deemed complete, the Engineer shall confirm acceptance in writing.

Where witnessed tests are not required by the Contract or waived by the Engineer, the complete test certificates including technical annexes shall be forwarded to the Engineer:

- a) either within two (02) weeks after shipment of the respective goods together with any other commercial document issued at the time of shipment; b) or within two (02) weeks after receipt of such waiver.

The Engineer may require the Contractor to remedy a failed test or inspection may require through supply of new parts from the manufacturer or return to manufacturer's plant of damaged parts for repairs if such repairs are still technically deemed feasible by the Engineer.

Any equipment used in testing shall in all respects comply with the appropriate safety regulations and/or requirements regarding electrical apparatus for the safety of the Plant and the men working thereon.

The Contractor shall make sure that all sub-contractors are given copies of the relevant parts of the Specifications. Full details of the testing method proposed for each item shall be submitted to the Engineer.

H.37.2 Cost for Testing

The Contractor shall bear all costs of Third Party as may be required from time to time and of the Engineer if required to carry out inspections at places other than on the site or in the Contractor's storage facilities close to the site. Such costs

of the Engineer shall comprise the per-day-fee, travel and accommodation cost and all other incidental costs occurring during the performance of test and inspection.

H.37.3 Test Instruments and Equipment

The Contractor shall satisfy the Engineer as to the accuracy of all instruments required for the tests.

kW-meters and kVAR-meters shall be checked for correct rotation and creep tests shall be carried out to ensure that the meter is inoperative with voltage alone if the secondary of the current transformers is left connected with the primary current interrupted.

H.37.4 Factory Tests

These are inspections and tests, at the place of manufacturing and apply for mechanical (e.g. pumps) and electrical items of equipment (e.g. instruments). Factory tests shall be carried out by the manufacturer according to the relevant standards and the manufacturer shall issue the relevant certificates.

The Engineer or his representative reserves the right to carry out pre-shipment inspections and witnessed testing at the manufacturer's facilities. All items of the plant shall be liable to works inspection at reasonable times by duly authorised representatives of the Engineer.

Each consignment of material and equipment delivered to the Site shall have been tested at the manufacturer's facilities or other approved place in accordance with the appropriate standard. The Contractor shall provide the Engineer with the manufacturer's test report for each such consignment before delivery to Site.

Whilst the Engineer shall be provided with facilities to witness testing and/or inspection of all items of equipment at the manufacturer's works, he may at his discretion advise that part of the tests shall proceed in his absence, the tests shall be made as if in his presence.

The Contractor shall submit to the Engineer a duly countersigned copy of the readings of any witnessed test and, within two weeks after completion of any witnessed or unwitnessed tests, a complete test certificate.

The Contractor shall submit to the Engineer un-witnessed factory test certificates where applicable giving a detailed record of all tests performed.

If after inspecting, examining, or testing of any material or equipment, the Engineer shall decide that such items or any part thereof is defective, or not in accordance with the Specification or performance requirements, he may reject the said items or part thereof, giving to the manufacturer within a reasonable time, notice in writing of such rejection, stating therein the ground upon which the said decision is based..

As and when the Engineer is satisfied that the equipment shall have passed the required tests he shall notify the Contractor in writing to that effect.

Copies of test certificates shall be included in the As-Built Documentation as detailed elsewhere.

H.37.5 Material and Design Qualification (DQ)

The Contractor has to submit the complete electrical design including material specification for Engineer's approval prior to any installation work and material order.

Shop Drawings The Contractor shall submit complete shop drawings of all electrical and I&C equipment in accordance with this specification. Such shop drawings shall include all electrical and I&C requirements,

weights, wheel loads, dimensions, and clearances required. Trade mark, model, and catalogue number, destination, description and testing data shall be indicated.

H.37.6 Factory Acceptance Test (FAT)

Prior to installation on site, the Contractor has to request for the factory acceptance test (FAT) by the Engineer. FAT shall comprise but not be limited to the main components of the electrical system e.g. MCC, electrical panels, gen set. The Contractor has to submit a request for FAT minimum 2 weeks prior to scheduled FAT date. The Contractor is responsible to organize FAT test protocols. FAT tests shall be confirmed by the signatures of the Contractor and the Engineer.

H.37.7 Installation Qualification (IQ)

After installation on site but prior to energization and commissioning of all components, the Contractor has to request for installation qualification (IQ) by the Engineer. The Contractor executes the tests and he is responsible to organize the IQ test protocols. IQ tests shall be confirmed by signature of the Contractor and the Engineer. Confirmed IQ protocols are prerequisite for commissioning.

H.37.8 Operation Qualification (OQ)

After commissioning and internal test procedure the Contractor has to request for operation qualification (OQ) by the Engineer.

The internal test procedure prior to OQ comprises but is not limited to:

1. System setup

All components of the system shall be set up as per design. A signed setup protocol shall be provided by the Contractor as part of the OQ.

2. Loop check

After the entire system has been installed ready for operation, a comprehensive data link test has to be executed. The link test comprises a complete functional test procedure from the sensor to PLC and to the SCADA (display, messaging system, archives, logs). The Contractor executes the tests and he is responsible to organize the loop check protocols. A signed loop check protocol shall be provided by the Contractor as part of the OQ. They are also part of the final acceptance inspection.

3. Functional test

After commissioning, the Contractor has to execute the functional test of the systems. All interfaces and interlocks of the system shall be fully tested. The Contractor executes the tests and he is responsible to organize the loop check protocols. A signed functional test protocol shall be provided by the Contractor as part of the OQ.

The OQ plan and schedule has to be clarified and approved by the Engineer, who will attend the test procedures.

In case that at the time of Tests on Completion connections to the public power supply have not been completed by the public electricity provider, the tests shall be carried out with power generated from the stand-by generating sets.

The Contractor shall provide for the tests:

- All skilled and qualified operating and test staff for the testing of all equipment;
- Provisions and disposal of all services, lubricants, and fuels and electricity;

- All measuring and testing instruments to demonstrate that the equipment fulfils the requirements, in particular instruments to monitor transient processes such as surges, etc.

H.37.9 Final Acceptance Test

All parts of the previous test procedure are prerequisite for final acceptance test of the system. The Contractor is responsible to provide all necessary documents and has to request for final acceptance test at least two weeks prior to schedule inspection date.

The Contractor, on completion of testing and commissioning of the installation/system shall submit to the Engineer all test results accompanied with the completion certificate as stipulated in Appendix 6 of 16th Edition of the IEE Wiring Regulations – BS 7671: 2008. The installation / system shall not be considered complete without this certificate. If the Contractor fails to produce these documents within one month from the date of Tests on Completion, the Engineer may employ the services of Third Party to produce these documents and all costs shall be borne by the Contractor.

H.38. CHLORINE GAS DETECTION AND RESIDUAL ANALYSIS

This Section covers the supply, installation, testing and commissioning of the chlorine gas leak detection system and the residual chlorine analyzers associated with the chlorination facilities. The system shall interface with the mechanical chlorination equipment, the ventilation system and the emergency chlorine scrubber to provide automatic protection in the event of a chlorine gas leak.

H.38.1 Chlorine Gas Detector

One (1) chlorine gas detector shall be provided at the chlorination room, served by two (2) sensors: one in the chlorine storage room and one in the chlorinator room. The gas detector system shall consist of sensor modules mounted at the gas detection sites and a receiving unit mounted in a gas-free environment, the receiver being compatible with the chlorine sensor modules.

The detection sequence shall operate in stages. Upon detection of chlorine gas by either sensor at 1 ppm, the chlorination system shall shut down completely, the exhaust fan shall be activated, and visible and audible alarms shall be energized. If the chlorine gas concentration reaches 3 ppm, ventilation shall be shut off and the emergency chlorine scrubber shall become operational at full capacity, accompanied by high-level audible and visible alarms.

The gas detectors shall have a range of 0 to 10 parts per million of chlorine with a minimum display resolution of 0.1 ppm. Each detection point shall have two independent alarm set points adjustable from 5% to 100% of range, with separate alarm LEDs and an integral audible horn. The sensors shall be fitted with an integral gas generator that automatically tests the sensor daily with an electrochemically produced gas sample, sounding the integral alarm if the sensor fails the self-test.

H.38.2 Receiver, Power and Sensor Modules

The system shall consist of two receiver modules and a separate power supply module, rail-mounted in a NEMA 4X (or IP66 with corrosion protection) enclosure suitable for wall mounting, with a clear hinged polycarbonate window and push-button latches. One receiver module shall be provided for each gas sensor to provide separate alarm functions. Each gas-specific receiver module shall contain four separate LED indicators for warning, alarm, sensor failure and power status, three alarm relays assigned to the two alarm set points (configurable for normal/fail-safe, latching/non-latching and fast/slow operation), and a fourth relay to indicate sensor failure. A four-digit LED display for gas concentration and a 4 – 20 mA output signal proportional to gas concentration shall be provided.

The power supply module shall accept any alternating current input between 110 and 220 V, 50 Hz and automatically convert it to a 13.7 VDC output for powering the receiver modules, with loss of input power indicated by a built-in power failure relay. A battery back-up system, consisting of a sealed lead-acid battery in a separate enclosure, shall maintain all gas detection functions for a minimum of 12 hours in the event of a power failure, and shall be continuously and automatically recharged.

The sensor/transmitter shall be housed in a NEMA 4X (or IP66 with corrosion protection) enclosure suitable for wall mounting, of the electrochemical type with an operating life of two (2) years, requiring no addition of chemicals. It shall be powered from the receiver through a two-conductor cable that also transmits a current-pulse position signal representative of gas concentration. Supplemental audible horns shall be electro-mechanical diaphragm-type devices with a stainless steel diaphragm producing approximately 100 dB at 3 metres, rated 220 V at 50 Hz, in a rugged NEMA 4X (or IP66 with corrosion protection) enclosure, surface mounted and connected to the auxiliary external contacts of the gas detector. Only manufacturers with a minimum of ten (10) years documented experience in chlorine gas detector systems shall be considered.

H.38.3 Chlorine Residual Analyzer

Residual chlorine analyzer units shall be provided for the inlet (flash mixer) and outlet (contact tank) of the works, each with at least one sampling point. The analyzer shall use a galvanic measurement cell to continually monitor the targeted species, and the measurement cell shall be self-cleaning through the action of a continuously driven motor cleaning mechanism. The system shall measure residual chlorine in continuously flowing water and shall incorporate a temperature sensor to compensate for signal fluctuations caused by temperature changes, together with a pH buffer feed system to control the pH of the water sample.

The analyzer shall be equipped with a complete PID control program that can be enabled or disabled, and shall be capable of operating as proportional (flow pacing), set-point (residual) or PID (compound loop) control. A data logger shall be available for automatically recording the analyzer output data (residual, temperature and pH where applicable) at a selectable frequency. The analyzer outputs shall be integrated with the plant monitoring and control system.

Technical Specifications

Solar Photovoltaic Works

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1 General

1.1 Scope of the Specification

This Section covers the particular specifications for the construction, supply, installation, testing and commissioning of solar photovoltaic (PV) power plants with critical loads, consisting of a PV generator, on- grid inverters, hybrid solar variable frequency drives (VFD), a PV (solar-diesel) controller, data loggers and auxiliary equipment, together with the necessary training and all related operation and maintenance documentation. The works shall be executed in accordance with the Employer's requirements, the Bill of Quantities and the approved shop drawings.

The objective of the PV system is to operate the water pumping stations and water treatment plants in off- grid mode for a defined number of hours per day during sunny conditions, to reduce annual energy costs relative to power generated from the public network, and to reduce environmental impact. Where a facility has a functioning public supply, a diesel generator and an added renewable source, the resulting hybrid system shall be configured to manage all three sources safely.

1.2 Functional Configuration and Modes of Operation

The hybrid solar PV system shall be coupled at the main distribution board of the plant and shall feature a fuel save controller to manage operation in parallel with the diesel generator and the grid. The fuel save controller shall control the active and reactive energy from the PV inverters, monitor which source (generator or mains) is connected to the load, and manage the spinning reserve in the system. The system shall provide the option of zero feed-in to the grid before a net meter is installed, and shall export surplus energy to the grid after a net meter is installed. When running in parallel with the diesel generator, the controller shall curtail surplus PV production to maintain at least 25% load on the generator.

In Grid Mode, when grid supply is available, the PV generator shall reduce consumption from the utility grid by parallel connection and load offsetting, with net metering applications submitted and followed up by the Contractor. The PV system shall be set to zero-export mode until net metering is installed. In Fuel Reduction Mode, automatically triggered when the grid is shed and the generator is running, the fuel save controller shall synchronise the PV penetration while respecting the generator's minimum load capacity, and shall protect against fault current, voltage rise, reverse power flow and neutral voltage displacement. In the absence of communication between the PV inverters and the fuel save controller, the inverter fall-back settings for active and reactive power shall be set to zero in the fastest time possible and the main PV contactor shall open to guarantee the safety of the system.

1.3 Contractor's General Scope of Work

The Contractor shall construct, supply, install, test, commission and provide training for one main solar photovoltaic system per site, generally consisting of PV modules, a metallic support structure, inverters, hybrid variable frequency drives, data loggers, PLCs, HMI and auxiliary equipment. The Contractor shall be responsible for the entire infrastructure required to deliver energy to the required load at each facility, including all connections to the existing installation and any required modification or replacement of existing equipment for proper operation.

The Contractor shall provide all necessary calculation notes, including inverter and PV panel configuration, DC and AC cable calculations, wind load calculation and pull-out tests, and shall submit data sheets and samples for approval of all material to be installed. The Contractor shall submit PV simulation and calculations demonstrating that the selected system meets the performance requirements, point-to-point wiring diagrams for the entire system, and a bill of material

listing all components by quantity and part number. The Contractor shall be responsible for the functioning of the system such that no PV plant is in blackout, and shall deliver as-built drawings of the PV system at each facility.

The integration of the PV system shall be carried out in close coordination with the Employer and the treatment plant operators, and cable routing shall be discussed and approved by the Engineer in coordination with the facility operators. In the event of damage during the construction period, the Contractor shall replace any damaged PV panels within 72 hours and any inverter or VFD within thirty (30) calendar days, ensuring the system continues running in the interim.

2 Particular Specifications for Solar PV Systems

2.1 PV Plant Simulation

Where the Contractor proposes a modification to the initial design, a complete photovoltaic simulation report, calculation notes and justifications shall be provided for the verification and final approval of the Employer and the Engineer.

2.2 Site Preparation

The land allocated for the construction of the solar PV plant shall have been relinquished to or already owned by the Employer. Sites shall be prepared prior to installation, including removing obstacles, adjusting the ground level, excavation and backfilling, rehabilitating existing structures, and the concrete works necessary for the PV support skeleton. The natural ground shall be adjusted as necessary to allow the steel structure construction and PV module mounting, and obstructions that might affect the function of the PV modules shall be avoided.

A site survey shall be carried out to locate and excavate the exact locations and sizes of the foundations for the steel structure. The foundation design shall be verified based on the Contractor's installation topology and via calculation note when needed; adjustments may be made on condition that the concrete strength and total volume of concrete are equal to or greater than the approved design. All civil works shall be implemented in accordance with the Engineer's instructions and the approved shop drawings.

2.3 Metal Structure and Mounting Method

Support structure mounting arrangements shall comply with applicable building codes, regulations and standards. Particular attention shall be given to wind loads on the PV generators and their structures so that they withstand winds of up to 140 km/h. All structures shall be made of corrosion-resistant materials such as aluminium or hot-dip galvanised steel. The use of hot-dip galvanised steel mounting structures shall include epoxy paint or a similar approved zinc paint as primer, and a solvent-based two-component aliphatic polyurethane finish coat, as protection against corrosion on welding spots. All welding joints shall be fully welded, reasonably smooth and uniform, and painted with pre-approved paint.

The array structure shall be made of hot-dip galvanised mild steel hollow sections of size not less than 80 x 40 x 2.5 mm for main rafters and columns and 40 x 40 x 2.5 mm for bracing, with a minimum galvanisation thickness of 70 microns. All nuts and bolts shall be of good quality stainless steel. The minimum clearance between the lowest part of the module structure and the developed ground level shall be not less than 500 mm. The structure shall be designed to allow easy replacement of any module, to permit simple mechanical and electrical installation, to support the modules at the given orientation and to transfer mechanical loads to the ground, and to withstand a wind speed of 140 km/h while occupying minimum space.

Where the Contractor proposes steel structures in replacement of galvanised steel arrays, the steel structures shall have corrosion treatment with epoxy coating of 2 x 70 microns. All bolts, nuts, guy-wires and fasteners shall be of stainless steel. All hollow tube endings shall be closed with a welded galvanised plate of the same thickness, smoothed and painted, or with suitable plastic or rubber covers to prevent water infiltration. The legs of the structures shall be fixed and grouted in concrete foundation columns, tie beams or upstands, with concrete of 350 kg/m³ Portland cement and 30 MPa compressive strength at 28 days. A written warranty of ten (10) years shall be provided for the steel structure and the clamps.

3 Materials and Equipment

3.1 General Instructions

Equipment shall be the latest standard product of the manufacturer and comply with the specifications, regulations and international standards. Equipment shall generally be supplied in complete factory- assembled units ready for installation, and the various components of the same system shall be from the same manufacturer. Equipment and materials shall be stored under cover, free from humidity, dust, debris and rodents, with heat- and humidity-sensitive equipment kept in climatically conditioned areas until installed. All equipment supplied shall carry the original manufacturer's warranty.

3.2 PV Modules

PV modules shall be high-efficiency crystalline silicon modules complying with IEC 61215 edition 2, classified as Class A or B according to IEC 61730, and complying with IEC 61701 (salt mist corrosion) and IEC 62716 (ammonia corrosion). The module rated power shall be at least 580 Wp at STC with a positive tolerance of up to 5 Wp, and the conversion efficiency shall be equal to or greater than 20.7% under STC. Cells shall be protected by anti-reflective coated tempered glass, the module shall withstand loads up to 5400 Pascal, and the supplied module DC voltage shall be not less than 1000 VDC. Only certified mono- crystalline silicon half-cut-cell modules from Tier-1 manufacturers (as per the latest Bloomberg Tier-1 listing) shall be accepted.

Modules shall be tested through at least one recognised quality and durability programme (for example Fraunhofer PVDI, Atlas 25+, PVEL, NREL Qualification Plus, VDE or TUV Sud Thresher), and proof shall be submitted with clear certificates and I-V curves. The PV modules shall have a minimum manufacturing warranty of ten (10) years and a performance warranty of at least twenty-five (25) years, guaranteeing at least 90% of nominal rated output for the first 10 years and 84% for the subsequent 15 years, or equivalent linear power output. Modules shall be clearly labelled with a permanent data plate, incorporate measures against potential induced degradation (PID), and have outside junction boxes with bypass diodes to prevent circuit breakage due to partial shading.

3.3 Cables

Cables shall conform to IEC 60502, single- or multi-core, of 660 V / 1.1 kV grade as required. Cable sizes shall be selected to keep the voltage drop of the entire solar system to a minimum. Clear labelling shall be provided for AC and DC cables at extremities and connection points, and all cables shall be provided with UV-resistant printed ferrules and be labelled at source, en route and at end of connection. All cables shall run inside conduits or cable trays, with power lines separated from control and signal cables. PVC conduits shall not be used for outdoor or exposed installations. Underground power and control cables shall be laid in trenches with sand bedding, warning tape and a bare copper earth bonding cable as detailed on the approved shop drawings, with backfill compacted to at least 90% relative compaction.

S.3.3.1 DC Cables

The maximum allowed DC voltage drop shall be 3%. All DC cables and connectors shall be of solar grade, robust and durable under high temperatures, UV radiation, rain, humidity and dirt as per IEC standards. The DC cable outer sheath shall be electron-beam cross-linked XLPE, flame retardant and UV resistant; 4 mm² and 6 mm² cables may be used. DC cables shall have a temperature rating higher than 40 degrees C above ambient, ozone resistance to EN 50396, weather and UV resistance to HD 605/A1, be halogen-free, double insulated (Class II), and have a voltage rating of at least 1000 VDC.

S.3.3.2 AC Cables

All AC cables shall be multipolar with double insulation (Class II), sized for minimum voltage drop with a maximum drop limited to 5%. All cables shall run in appropriate wireways. The Contractor shall supply and install the AC cables between the main AC panel and the main distribution board. An aluminium aerial bundle cable (ABC) compliant with BS 7870-5, HD 626 S1 and EN 60228 shall be used for the PV injection point from the new electrical room to the MDB room.

S.3.3.3 Cable Terminations

Cable terminations shall be made with suitable cable lugs and sockets, crimped to the manufacturer's recommended torques using torque wrenches, and passed through brass compression or screw-type connectors and cable glands at the entry and exit points of enclosures. Power cables shall be terminated in totally enclosed boxes. Aluminium cores shall be terminated using approved bimetallic connectors with factory prefilled joint compound. Heat-shrink plastic shall be used for cable terminations, and glands for armoured cables shall provide a positive armour clamp and earth continuity capable of withstanding the full fault current of the system for one second.

S.3.3.4 Conduits and Cable Trays

PVC conduit shall be round, high-impact, non-flame-propagating type, not used for any outdoor installation or areas receiving direct sunlight. EMT and RGS conduit shall be hot-dip galvanised steel, screwed type, of not less than 20 mm diameter, with all steel conduits grounded. All cable trays shall be heavy-duty perforated type manufactured from hot-dip galvanised steel with a coating of 350 g/m², with accessories from the same manufacturer and no site fabrication permitted. AC cable trays shall have 25% spare capacity, all outdoor trays shall be supplied with covers, and all trays shall be grounded. DC cables may be bundled in exposed corrugated stainless steel (316L) conduits fixed to the solar structure, rated IP68, with high mechanical, abrasion and corrosion resistance.

3.4 On-grid Inverters

On-grid inverters shall be provided as shown on the approved shop drawings, schedules and Bill of Quantities, with at least four MPPTs and three string inputs each, all of the same manufacturer. Inverters shall be capable of synchronising in parallel with a back-up generator in addition to the public grid, with 380 V three-phase 50 Hz output and an MPP tracking window of 430 VDC to 720 VDC or larger. The minimum European efficiency shall be at least 97.9%. Inverters shall be provided with insulation testing on the DC side, DC fuses on both polarities, a PV-specific type 1+2 surge arrester on the DC side and a type 1+2 surge arrester on the AC side, and shall accept control signals from the fuel save controller for power curtailment and active/reactive power control. Inverters shall be rated for a minimum ambient of 40 degrees C, comply with IEC 62109-1/2 and VDE 0126-1-1 or similar, and carry a minimum warranty of five (5) years.

3.5 Hybrid Inverters

Hybrid inverters shall work with batteries to store excess power, and shall be provided as shown on the approved shop drawings, schedules and Bill of Quantities with at least one MPPT per inverter. They shall be capable of charging battery banks and supplying AC current from the battery storage rack, with 220 V single-phase 50 Hz output, IP65 minimum, and MODBUS or CAN communication allowing reading and writing on the inverter. A PV-specific type 1+2 surge arrester shall be provided on the DC side and a type 1+2 surge arrester on the AC side. The battery voltage range shall be 40 – 60 V, the MPPT range 150 – 425 V, the minimum European efficiency at least 96%, and the minimum warranty five (5) years.

3.6 Batteries

Lithium iron phosphate battery banks shall be provided to supply the UPS system of the inverter room, supplied with their respective battery management system (BMS) and installed in an enclosed rack system rated NEMA 1 or higher in a dedicated location per the manufacturer's recommendations. The BMS shall protect the cells against abnormal temperature, current, voltage, state of charge and state of health. Batteries shall have more than 6000 cycles at 95% depth of discharge, a 48 V nominal operating voltage, at least the rated capacity at the C20 discharge rate, a working temperature range of 0 – 50 degrees C, authentication to VDE/IEC 62619/CE/UN 38.3, a modular design, and a minimum warranty of five (5) years.

3.7 Solar Diesel Controller

The PV plant controller shall be a solar-diesel (fuel save) controller with PLC units compliant with the latest editions of IEC 61131, and with a minimum track record of four years in similar conditions. It shall be compatible with the proposed inverters and shall continuously monitor the diesel generator and solar inverter outputs via dedicated meters. The Contractor shall supply and install power meters, dry contacts, current transformers and necessary measurement accessories on the generator and grid power lines. The controller shall be maintained online even during power transfers, for which a small UPS shall be supplied, and shall communicate via RS485 and Ethernet.

The fuel save controller shall protect the diesel generators and guarantee their proper operation (minimum part load of 25%, spinning reserve and reverse-current protection), actively control the reactive power output from the PV inverters, provide zero feed-in to the grid when not required, prevent back-feeding into the generator, export surplus energy when a net meter is installed, provide gradual ramp-up and ramp-down of PV power, and provide emergency shutdown of the PV system. Hard-wired protection shall disconnect the solar inverters via contactors controlled by a reverse-current relay at the generator input if reverse current flows or if communication between the data loggers and the controller fails. All operating parameters shall be logged, MODBUS communication shall be provided, and the minimum warranty shall be two (2) years.

3.8 Electrical Panels

Electrical panels shall be Class II boxes suitable for outdoor use, with a minimum IP65 protection where installed outdoors, UV resistant and fire retardant, with components as per the single line diagram. All boxes shall carry tracking labels and warning signs in Arabic and English, be labelled with the associated inverter and MDB numbers as per the as-built drawings, have suitable cable entry points with glands preserving the IP rating, and be properly grounded. AC panel busbars shall be rated for normal current as specified and braced for the specified short-circuit duty, of copper sized to limit the temperature rise to a maximum of 90 degrees C, with bolted copper-alloy connections, a full-size insulated neutral continuous through all sections, and electro-silver-plated contact surfaces.

3.9 Interconnection to the Facility Grid

The interconnection to the grid shall be made in the existing main panel at the facility, if it can be adapted to house more devices, or in a new additional panel installed beside the existing one, in coordination with the Employer and the beneficiary and with minimum disturbance to the facility grid. For any deviation from the original design regarding equipment location, cable lengths or the connection point, the Contractor shall check and recalculate that the connection point panel can handle the solar injected capacity, that the busbar rating can handle the solar generation, and that there are no drawbacks on the system short-circuit capability. A load flow analysis shall confirm that the voltage drop at the point of common coupling after PV connection is less than 2%, and the total PV internal loss from the panels to the point of common coupling shall be less than 3%.

3.10 Earthing System

The Contractor shall supply and install a proper earthing system and ground all electrical items accessible to personnel, including solar module frames, the mounting structure, the fence, the solar VFD, inverters, monitoring and control racks, electrical cabinets, cable trays, EMT and RGS pipes, combiner and junction boxes, and data monitoring equipment. Suitable accessories shall be used for bonding between copper and metallic structures to avoid potential-difference-induced corrosion, and piercing PV clamps shall be used to bond PV panel frames on the same row. A continuity test shall be carried out after each array connection. The earth resistance shall be tested by a calibrated earth tester in the presence of the Employer's representative and shall not exceed 5 ohm, with earthing installed in accordance with BS 7671.

3.11 DC Side Surge Protection

A type 2 surge protective device (SPD) shall be provided for the DC strings where the distance between the inverters and the PV panels exceeds 10 metres, installed within 10 metres of the PV panels. The SPD shall have an I_{max} of at least 40 kA according to IEC 61643, comply with IEC 62305-1 and IEC 62305-3, and incorporate an electromagnetic interference (EMI) filter to protect the SPD and the equipment from electromagnetic noise.

4 Ancillary Works

4.1 Fire Fighting Equipment

Portable fire extinguishers shall be provided near the PV installation site and the main electrical rooms as shown on the approved shop drawings and the Bill of Quantities. The extinguishers shall be of the dry chemical A, B, C type, UL listed, 4.5 kg, with aluminium valve and handle and hose discharge, suitable for outdoor installation, provided with a wall bracket installed on the nearest wall or structure, and with a minimum warranty of two (2) years.

4.2 Fence Around the PV Park

Where required, the Contractor shall erect fences, gates and wickets in accordance with the layout and details shown on the approved shop drawings and described in the Particular Specification. The ground along the fence alignment shall be levelled to provide an even gap between the bottom wire and the ground surface. All main and tie wires, fence steel wires and metal parts shall be hot-dip galvanised and polyester-coated. Installation shall not commence before the concrete foundations have hardened sufficiently, in no case before 14 days from pouring. Entrance gates shall be double leaf and wickets single leaf, fabricated from standard galvanised water pipe and fittings with bracing, and covered with 5 x 5 cm wire mesh of 3 mm diameter galvanised and plastic-coated wire, complete with locks and stops.

4.3 Safety Signs

The Contractor shall supply and install safety signs treated against oxidation, including “Danger High Voltage” and “Warning – Do Not Touch”, with minimum dimensions of 20 cm height and 50 cm length. Signage shall be provided at all disconnecting means, including switches and circuit breakers, in accordance with NEC article 690.17.

5 Instrumentation and Control

5.1 Monitoring and Data Acquisition

The Contractor shall supply and install a data acquisition unit (data logger) for efficient plant operation and control, compatible with all measuring components. All measurements shall be logged locally and available remotely through an internet connection, including data from the weather station, the inverters, the energy meters and the solar-diesel controller. A weather monitoring station shall be provided complete with sensors bearing valid calibration certificates, including as a minimum a global horizontal irradiance pyranometer, a plane-of-array irradiance pyranometer, a shielded and ventilated ambient temperature sensor, a module temperature sensor and a wind speed sensor.

Energy meters measuring four-quadrant power parameters, compatible with the solar-diesel controller, shall be installed at the injection points. Data acquisition software shall be provided, and the system shall operate through both GSM and LAN with all accessories such as SIM cards and modules. Remote monitoring access shall be provided to the Employer and the facility operator. Logs of all inverter measurements shall be recorded, including AC, reactive and apparent power, frequency, grid AC voltage and current, DC voltage and current, and daily delivered energy. A UPS with 1 kWh battery storage and 1000 W rating shall power all monitoring and controller equipment, and the system shall comply with the latest editions of IEC 61131, with a minimum warranty of two (2) years.

5.2 PV Station Sensors

Each PV station shall be equipped with an integrating pyranometer or solar cell-based irradiation sensor, complete with calibration certificate, mounted in the plane of the array with readout integrated into the data logging system. Temperature probes shall be provided for recording the solar panel temperature and ambient temperature, with readouts integrated into the data logging system, and a minimum warranty of two (2) years.

5.3 Dynamic Display Panel

A 50-inch TV screen and display interface for indoor use shall be provided at a location approved by the Employer and the plant management, displaying as a minimum the solar penetration, demand load, generator contribution, public power availability, running generator indication, total produced energy, cumulative CO2 emissions saved, weather data, cell temperatures and an alarm display page. The graphic design shall be approved by the Employer’s Engineer, and the Contractor shall supply and install a communication device between the plant remote monitoring system and the display.

6 Submittals, Testing and Deliverables

6.1 Labeling

Each item of equipment shall have a nameplate bearing the manufacturer’s name, address, model number and serial number securely affixed in a conspicuous place. Tags shall be provided for each power cable or wire in manholes, hand-holes and vaults. Signage shall be provided at all disconnecting means in accordance with the local code, and weather-

resistant warning labels regarding safety hazards and emergency shutdown procedures shall be affixed to the technical room.

6.2 Shop Drawings

The Contractor shall provide detailed shop drawings, including but not limited to the dimensions of arrays with tilt and orientation, the total number of modules, access roads for equipment and maintenance, DC and AC cable routing, and the electrical room showing all components. The Contractor shall also submit manufacturer equipment data sheets, PV calculations demonstrating compliance with the performance requirements, point-to-point wiring diagrams, a bill of material, system mounting details, and the design calculations and drawings of the structural supports for the photovoltaic array.

6.3 Datasheets and Certifications

The Contractor shall provide equipment datasheets, catalogue pages and certificates of compliance to standards clearly showing the specification of the material to be supplied. All documentation shall be arranged in a folder with a clear table of contents, provided in one hard copy and three soft copies.

6.4 Testing and Commissioning

The Contractor shall verify that the system output is within 5% of the calculated array power, taking into account irradiance, mismatch and dust factor, array temperature, wiring efficiency, inverter efficiency and inverter output power, by measuring AC power and comparing it to the predicted power based on estimated irradiance. The Contractor shall submit a Testing and Commissioning Plan including a checklist of start-up requirements and safety tests, measurements of all cable insulation resistance, confirmation that all connections and terminations are tightened and strain-relieved, confirmation that all cables, conduits and boxes are secured to code, and the testing and commissioning of all electrical equipment in accordance with the applicable IEC standards. A physical checkout of the PV modules shall include checks for cracked or broken glass, delamination or water infiltration, broken or discoloured cells, and correct voltage and current output against manufacturer specifications. Results shall be recorded and submitted to the Employer and the Engineer.

6.5 Deliverables

The Contractor shall submit a detailed operation philosophy including the sequence of operations for the PV system with the existing generator, interconnection tables, a P&ID diagram, and a single line diagram showing ratings on all equipment and all wire and conduit sizes together with the details for interconnection of the PV array to the existing distribution system. The Contractor shall also submit an operation and maintenance manual including as-built drawings and technical documentation, soft and PDF copies of any program (the software being the property of the Employer with all credentials provided), the station testing report upon commissioning, and training for the technical staff on the operation of the PV system.

7 Particular Specifications for Civil Works

7.1 Excavation

The Contractor shall carry out excavations at the indicated locations to the depth directed by the supervising engineer or based on the geotechnical investigation findings. All excavations shall be deemed to consist of common excavations

regardless of the nature of the encountered soils. The Contractor shall verify the natural ground level where PV support structures are to be erected and shall carry out the topographical setting-out of the final support structure locations. Where dewatering is required, the Contractor shall divert or pump water outside the excavated pit throughout the period prior to construction of the concrete structure. The sides of excavations shall be supported where needed, a protective fence shall be installed beside open trenches with warning lights for night viewing, and all additional excavated material shall be disposed of at legally designated dumping sites.

7.2 Backfilling and Structural Backfilling

Backfill material shall be placed in horizontal layers not exceeding 15 cm after compaction, completely filling the spaces between the excavation lines and the structure without voids, and compacted to the density of the adjacent natural earth. The sides and bottom of the excavation and the backfill material shall be moistened before backfilling to obtain the required moisture content, and each layer shall be compacted by approved pneumatic tampers. A 10 cm ground covering of drainage gravel over a 10-mil polyethylene sheet shall be provided under and between the PV panels to prevent weed growth and muddy conditions. Aggregate subbase and base courses shall be well graded and compacted to the specified CBR and proctor densities, and shall be tested as directed prior to placement.

7.3 Concrete

Concrete shall be used for PV support structures, fence construction and the rehabilitation of control, chlorination and valve chambers and retaining walls, and shall have a minimum compressive strength on cylinder of 300 kg/cm² at 28 days. Concrete shall be composed of cement, sand, broken rock or gravel and water, well mixed to the proper consistency, with a cubic metre of concrete comprising a minimum of 350 kg of Portland cement, 800 litres of gravel of maximum size 20 mm, and 400 litres of sand free from organic materials (marine sand is strictly forbidden). The water/cement ratio shall not exceed 0.42 by weight. The Contractor shall be responsible for the concrete mix design and shall obtain the Engineer's approval; cylinders shall be taken on site for crushing tests at 7 and 28 days.

Cement shall comply with the standard specifications for Portland cement, equivalent to AASHTO M85 type I, II, III or V, delivered in 50 kg bags and protected from damage by climatic conditions. Sand shall be hard, dense, durable, non-organic and free from injurious amounts of dust, lumps, shale, alkali or organic matter, with a fineness modulus between 2.75 and 3.25. Broken rock or gravel shall be hard, dense, durable and clean, graded to produce workable, dense and impermeable concrete. Ready-mix concrete may be used subject to the supervising engineer's approval and shall comply with BS 1926, transported in a revolving drum and placed within 90 minutes of adding water. Admixtures shall be approved for compatibility with the cement; admixtures containing chlorine shall not be used for potable water retaining structures. Water shall be of potable quality.

Concrete shall be transported and placed so as to prevent segregation, loss or contamination, placed within 30 minutes of mixing in layers not exceeding 500 mm and compacted by approved vibrators to a dense material free from honeycombing. Blinding concrete of 100 mm thickness (150 kg/m³) shall be cast before any foundation reinforcement. Hot-weather concreting above 20 degrees C shall observe the specified precautions, and concreting shall not be permitted when the concrete temperature at placing exceeds 38 degrees C. Newly placed concrete shall be protected from rain, drying winds and sun, and cured by approved methods for at least 7 days.

7.4 Reinforcement, Formwork and Tolerances

All steel bars for concrete reinforcement shall conform to AASHTO M31 grade 60, free from detrimental dirt, mill scale, rust, paint, grease or oil. Reinforcement shall be rigidly supported on approved metal supports and spacers, cut and bent

cold in an on-site fabrication shop to the specified bend diameters, accurately placed and securely fastened with wire ties, and inspected and approved by the Engineer before concrete is placed. Formwork shall be rigid, mortar-tight and free from openings, designed to permit easy removal without damage to the concrete, treated with approved mould oil, and cleaned by jetting with compressed air before concreting. The finished concrete tolerances shall not exceed the specified limits for alignment, grade, plumb, cross-sectional dimensions and slab thickness.

7.5 Finishing and Defects

All exposed concrete faces shall be hard, smooth and free from honeycombing, air and water holes and other blemishes, with 10 cm thick stamped concrete provided for the pavement around constructed structures. Surface finishing shall be by wood float, steel trowel, screeded, or bush-hammered / pattern-worked methods as specified, and buried areas shall be finished with a liquid asphalt flint coat and a bituminous protective coating as specified. The Contractor shall, on the Engineer's instruction, cut out and replace any concrete that does not conform to the specification, contains deleterious materials, is excessively honeycombed or damaged, is out of tolerance, has incorrect setting-out or inadequate cover, or has been inadequately protected or cured. Loading tests and core sampling shall be carried out in accordance with ASTM C39 and C31 where directed by the Engineer.