g. Automatic Valves:
    1. Automatic Inlet Shut Off Valve: Solenoid type, diaphragm actuated, normally closed, constructed of glass-filled Noryl thermoplastic.
    2. Automatic Membrane Flush Valve: Provide for purging the membranes with fresh water upon machine shut down.

h. Piping:
    1. Low Pressure Feed, Reject and Recycle Piping (75 psi and under): ASTM D1785, Schedule 80 PVC, socket welded and flanged.
    2. RO Product Tubing From Each Membrane Housing: ASTM D1785, Schedule 80 PVC, socket welded and flanged.
    3. Low Pressure Control and Pressure Gage Tubing: Polyethylene.
    4. High Pressure Reject and Recycle Piping (above 75 psi): ASTM A269, Type 304 Schedule 10 stainless steel with butt welded joints.
    5. High Pressure Control and Pressure Gage Tubing: 1000 psi burst nylon.

i. Controls:
    1. Electronic PLC or microprocessor controller providing automatic control for all operating functions. Motor starter panel. All in FRP enclosures rated NEMA 4. All wiring factory-installed and tested. Comply with Section 26 05 21, LOW-VOLTAGE ELECTRICAL POWER CONDUCTORS AND CABLES (600 VOLTS AND BELOW) and NFPA 70.
    2. Autoflush indicator and control to flush RO concentrate at shut down or at predetermined intervals.
    3. Warning Alarms: Low quality product, low feed pressure, high feed temperature.
    4. Automatic Shutdowns and Alarms: Low feed pressure, low product quality, pretreatment out of service, storage tank full.
    5. Status Indicators: Low feed pressure, low quality, flow alarm, high feed water temperature, product divert to drain valve open, pretreatment lockout, storage tank full.
    6. Pump Motor Starter: Comply with Section 26 29 11, LOW-VOLTAGE MOTOR STARTERS.

7. Miscellaneous Controls: Elapsed run time indicator, alarm horn, chemical pump receptacles, convenience receptacles, auxiliary contacts.

j. Instrumentation and Displays:
   1. All instrumentation readouts panel-mounted in FRP enclosures rated NEMA 4. All factory wiring. Comply with NFPA 70.
   2. Digital flow indicators for feed, product, reject, recycle.
   3. Pressure gages for inlet, cartridge filter outlet, RO feed, RO concentrate, and RO product. Refer to paragraph below.
   4. Conductivity indicator measuring product quality with digital displays, alarm relays and automatic temperature compensation.
   5. Conductivity probe mounted in the RO product.

k. Skid and Frame Assembly:
   RO machine shall be built on a skid and frame constructed of welded structural carbon steel. The entire surface shall be sand-blasted and coated with high solids epoxy coating.

E.2 pre-filter

a. Single multi-media filter sized for the RO machine inlet flow rate. Designed for suspended solids removal down to 5 microns. Automatic backwash cycle.
b. Media Tank: FRP designed for 150 psi. Pre-piped internal backwash distributor and filtered water collector.
c. Filter Media: Top layer of anthracite, middle layer of silica sand, bottom layer of multi-grade garnet. Install filter media at job site.
d. Backwash Cycle: Top-mounted, piston-operated control valve with pre-sized drain line flow control orifice. The cycle shall be initiated by and adjustable seven day electronic time clock.
e. Replacement Filter Media: Provide elements for one complete replacement.

E.3 Activated Carbon Filter

a. Single filter sized for the RO machine inlet flow rate. Designed to remove chlorine and prevent RO membrane damage.
b. Media Tank: FRP designed for 150 psi. Pre-piped internal backwash distributor and filtered water collector.
c. Filter Media: 12 x 40 mesh bituminous coal-based activated carbon. Install media at job site.

d. Backwash Cycle: Top-mounted, piston-operated control valve with pre-sized drain line flow control orifice. The cycle shall be initiated by and adjustable seven day electronic time clock.

E.4 RO Water storage tank

a. Free-standing, closed-top, flat-bottom, 500 litres total volume. Top access manway, PVC bulkhead fittings for high and low level alarm switches, RO permeate inlet, RO permeate discharge and drain. Install 0.2 micron tank vent filter at the top head. Vented to atmosphere.
b. Materials of Construction: Linear polyethylene in one piece.
c. Tank Water Level Control: Adjustable float switch that signal starting and stopping RO pump. High and low level alarm switches.

E.5 Pressure Gages

ASME B40.100, Grade A, 1% accuracy, 110 mm (4-1/2 inches) diameter, all metal case, bottom connected. White dials, black hands, graduated from 0 to 700 kPa (0 to 100 psi) and identity labeled.

E.6 Water Testing Equipment:

a. Furnish water testing equipment in a portable cabinet specially made for the installed equipment. Include sufficient materials for 6 months of normal testing procedures.
b. Silt Density Index (SDI) apparatus to measure degree of suspended solids feeding the RO membranes. Include pressure regulator, pressure gage, filter holder, 600 mL beaker, sample valve, tubing and 0.45 micron filter papers.
c. Test kit to measure total water hardness, total iron, free chlorine, pH.

E.7 Execution

a. Required Technical Services:

   Provide services of a qualified manufacturer's representative to check complete installation for conformance to manufacturer's recommendations, put system into service, make all adjustments required for full conformance to design and specified requirements, and perform all demonstrations and tests.
b. Flushing and disinfecting:
   1. Flush and disinfect new water lines and RO system and tank interiors in accordance with AWWA C651.

2. Material:
    - Liquid chlorine: AWWA B301.
    - Hypochlorite: AWWA B300.

E.8 Tests:

a. Operating: Tests shall be run in presence of Contracting Officers Technical Representative (COTR) or Resident Engineer (RE).

b. Procedure:
    1. Operate RO system at constant maximum required capacity for one hour after demineralized RO product water is produced. When necessary, waste product water to sewer to maintain above flow rate. Product water production shall begin when a sample shows that demineralization complies with requirements.
    2. Demonstrate all features of the control system including diagnostics and flow and cycle indications.

COOLING PLANT (15530)

A. General Requirements

a. Equipment shall have factory applied finish coat of machinery enamel unless otherwise specified.

b. Warranty: equipment is to carry manufacturer's warranty against defects in materials and workmanship for a period of one year after shipment.

c. Furnish equipment supplier with all necessary data such as available electric current characteristics, maximum and minimum ambient temperatures and humidities, altitude, water quality and other particular site conditions so that manufacturer will supply equipment to specifically suit Site conditions particularly for necessary derating in capacity for altitude and temperature, necessary class of insulation for electric motors, special construction for water quality, high temperatures and humidities, sandy environment etc.

d. Electric motors are to conform with the specification for electric motors given under "Electrical Works for Mechanical Systems" and with requirements given under equipment specifications for particular motor driving that equipment.

e. Equipment is shall be supplied from factory complete with all necessary accessories and components that are standard items of manufacturer or as recommended by him for good, safe and efficient operation of equipment irrespective of whether these are specified or not.

f. Pumps are shall be selected so that their operating point falls nearest to the point of maximum efficiency obtained from manufacturer's published data. Do not select pumps to operate near the end of their curve.

g. Horsepower rating of electric motors of pumps are to ensure non-overloading throughout the capacity range of pump.

h. Shop drawings for pumps: submit the following for approval, for each pump prior to shipment:

Certified performance curves showing job number, customer, customer order number, pump designation number shown on the Drawings, date of manufacture, model number, pump size, impeller diameter, impeller type, maximum impeller diameter pump can accommodate, rpm, flow- head characteristic curve, consumed horsepower curve, pump efficiency curve, cross-sectional drawing showing major components with parts numbers and parts list

Outline dimensional drawing showing overall dimensions, location of foundation bolt holes and size, location and rating of suction and discharge nozzles

recommended list of spare parts

installation, operation and maintenance instruction manual

details and wiring diagrams of pump controllers, starters, controls or other electrical device or accessory

special instructions for installation and connection of electrical device, control or accessory.

B. Air Cooled water chiller

Supply and install air cooled water chilled wherever shown on the drawings and as specified herein:

B.1 General

a. System Description
Microprocessor controlled, air-cooled liquid chiller utilizing screw compressors and low sound fans.

b. Quality Assurance
1. Unit shall be rated in accordance with AHRI Standard 550/590 (U.S.A.) latest edition and all units shall be ASHRAE 90.1 compliant.

2. Unit construction shall comply with ASHRAE 15 Safety Code, UL 1995, and ASME applicable codes (U.S.A. codes).

3. Unit shall be manufactured in a facility registered to ISO 9001:2000 Manufacturing Quality Standard.

4. Unit shall be full load run tested at the factory.

c. Delivery, Storage and Handling
1. Unit controls shall be capable of withstanding 150 F (65.5 C) storage temperatures in the control compartment.

2. Unit shall be stored and handled per unit manufacturer's recommendations.

B.2 Products

a. Equipment

1. General:
Factory assembled, single-piece chassis, air-cooled liquid chiller. Contained within the unit cabinet shall be all factory wiring, piping, controls, refrigerant charge (R-134a), and special features required prior to field start-up.

2. Unit Cabinet:
- Frame shall be of heavy-gage, painted galvanized steel.
- Cabinet shall be galvanized steel casing with a baked enamel powder or pre-painted finish.
- Cabinet shall be capable of withstanding 500-hour salt spray test in accordance with the ASTM (U.S.A.) B-117 standard.

3. Fans:
- Condenser fans shall be direct-driven, 9-blade airfoil cross-section, reinforced polymer construction, shrouded-axial type, and shall be statically and dynamically balanced with inherent corrosion resistance.
- Air shall be discharged vertically upward.
- Fans shall be protected by coated steel wire safety guards.

4. Compressor/Compressor Assembly:
    - Comprised of semi-hermetic twin screw type compressors.
    - Compressor motor shall be direct drive, 3500 rpm, protected by motor temperature sensors, suction gas cooled motor.
    - Capacity control shall utilize an infinitely modulating slide valve to modulate capacity from 100% to 15% full load.

5. Cooler:
    - Shall be a mechanically cleanable tubes in a shell-and-tube type cooler with removable heads.
    - Tubes shall be internally enhanced seamless-copper type rolled into tube sheets.
    - Shall be equipped with Victaulic-type water connections.
    - Shell and cooler heads shall be insulated with 3/4-in. PVC foam (closed-cell) with a maximum K factor of 0.28.
    - Design shall incorporate a minimum of 2 or 3 independent refrigerant circuits.
    - Cooler shall be tested and stamped in accordance with ASME Code for a refrigerant working side pressure of 220 psig. Cooler shall have a maximum water-side pressure of 300 psig.
    - Cooler shall have a cooler drain and vent.
    - Low-ambient temperature protection: unit shall have factory-installed cooler heater, and pumpout cycle to protect cooler from ambient temperature freeze down to 0° F (–17.8 C).
    - Cooler shall be provided with a factory-installed flow switch.

6. Condenser:
    - Coil shall be air-cooled Novation® heat exchanger technology (MCHX) and shall have a series of flat tubes containing a series of multiple, parallel flow microchannels layered between the refrigerant manifolds. Novation coils shall consist of a two-pass arrangement. Coil construction shall consist of aluminum alloys for fins, tubes, and manifolds in combination with a corrosion-resistant coating.
    - Tubes shall be cleaned, dehydrated, and sealed.
    - Assembled condenser coils shall be leak tested and pressure tested at 375 psig (2585 kPa).

7. Refrigeration Components:
   Refrigerant circuit components shall include replaceable-core filter drier, moisture indicating sight glass, electronic expansion valve, discharge service valves and liquid line service valves, and complete operating charge of both refrigerant R-134a and compressor oil.

8. Controls, Safeties, and Diagnostics:
    - Unit controls shall include the following minimum components:
        i. Microprocessor with non-volatile memory. Battery backup system shall not be accepted.
        ii. Separate terminal block for power and controls.
        iii. Separate 115-v power supply to serve all controllers, relays, and control components.
        iv. ON/OFF control switch.
        v. Replaceable solid-state controllers.

vi. Pressure sensors installed to measure suction, oil, economizer, and discharge pressure. Thermistors installed to measure cooler entering and leaving fluid temperatures and outside air temperature.

- Unit controls shall include the following functions:
  i. Automatic circuit lead/lag.
  ii. Capacity control based on leaving chilled fluid temperature and compensated by rate of change of return-fluid temperature with temperature set point accuracy to 0.1° F (0.05° C).
  iii. Limiting the chilled fluid temperature pulldown rate at start-up to an adjustable range of 0.2° F to 2° F (0.1 to 1.1° C) per minute to prevent excessive demand spikes at start-up.
  iv. Seven-day time schedule.
  v. Leaving chilled fluid temperature reset from return fluid and outside air temperature.
  vi. Chilled water pump start/stop control.
  vii. Chiller control for parallel chiller applications without addition of hardware modules and control panels (requires thermistors).
  viii. Timed maintenance scheduling to signal maintenance activities for strainer maintenance and user-defined maintenance activities.
  ix. Low ambient protection to energize cooler heaters.
  x. Single step demand limit control activated by remote contact closure.
- Diagnostics:
  i. The control panel shall include, as standard, a display:
    1) Touch screen display consisting of 1/4 VGA LCD (liquid crystal display) with adjustable contrast and backlighting.
    2) Display shall allow a user to navigate through menus, select desired options and modify data.
  ii. Features of the display shall include:
    1) Display shall be customizable and allow up to 72 data points.
    2) Display shall support both local equipment or network made for remote mount.
    3) Display shall allow access to configuration, maintenance, service, set point, time schedules, alarm history and status data.
    4) Display shall have one button for chiller on/off.
    5) Display shall include three levels of password protection against unauthorized access to configuration and maintenance information, and display set up parameters.
    6) Display shall allow for easy connection of a portable hand held technician tool to access information and upload and/ or download chiller settings.
    7) Display shall be compatible with the Carrier Comfort Network® (CCN) system and provide network alarm acknowledgement or indication and provide capability to fully monitor and control chiller.
    8) Display alarms and parameters shall be capable of being displayed in full text.
    9) Display shall be capable of displaying the last 50 alarms and will store a snapshot of a minimum of 20 status data parameters for each alarm.

10)Compressor run hours.
11)Compressor number of starts.
12)Compressor current.
13)Time of day:

- Display module, in conjunction with the microprocessor, must also be capable of displaying the output (results) of a service test. Service test shall verify operation of every switch, thermistor, fan, and compressor before chiller is started.
- Diagnostics shall include the ability to review a list of the 30 most recent alarms with clear language descriptions of the alarm event. Display of alarm codes without the ability for clear language descriptions shall be prohibited.
- An alarm history buffer shall allow the user to store no less than 30 alarm events with clear language descriptions, time and date stamp event entry.
- The chiller controller shall include multiple connection ports for communicating with the local equipment network, the Carrier Comfort Network (CCN) system and the ability to access all chiller control functions from any point on the chiller.
- The control system shall allow software upgrade without the need for new hardware modules.

- Safeties:
  i. Unit shall be equipped with thermistors and all necessary components in conjunction with the control system to provide the unit with the following protections:
     1) Loss of refrigerant charge.
     2) Reverse rotation.
     3) Low chilled fluid temperature.
     4) Motor overtemperature.
     5) High pressure.
     6) Electrical overload.
     7) Loss of phase.
     8) Loss of chilled water flow.
  ii. Condenser-fan motors shall have internal overcurrent protection.

9. Operating Characteristics:
   - Unit shall be capable of starting and running at outdoor ambient temperatures from 32 F (0° C) to 125 F (52 C) for all sizes.
   - Unit shall be capable of starting up with 95 F (35 C) entering fluid temperature to the cooler.

10. Motors:
    Condenser-fan motors shall be totally enclosed, air over, single speed, 3-phase type with permanently lubricated bearings and Class F insulation.

11. Electrical Requirements:
    - Unit primary electrical power supply shall enter the unit at a single location (all chiller voltage/ size combinations shall have the ability to accommodate 2 power supplies to meet jobspecific requirements).
    - Primary electrical power supply shall be rated to operate up to 125 F (52 C) ambient temperature.

- Unit shall operate on 3-phase power at the voltage shown in the equipment schedule.
- Control points shall be accessed through terminal block.
- Unit shall be shipped with factory control and power wiring installed.

12. Chilled Water Circuit:
    - Chilled water circuit shall be rated for 300 psig (2068 kPa). Units with optional pump package are rated for 150 psig (1034 kPa) working pressure.
    - Thermal dispersion proof of flow switch shall be factory installed and wired.
    - Optional hydronic package (sizes 090-160):
        i. Field pipe connections shall be Victaulic type.
        ii. Optional single or primary/stand-by operation pump systems. Dual pump systems shall have a pump discharge check valve.
        iii. Pumps shall be single stage design, for installation in vertical position and capable of being serviced without disturbing piping connections.
            1) Pump casing shall be of class 30 cast iron.
            2) The impeller shall be of cast bronze, closed type, dynamically balanced, keyed to the shaft and secured by locking cap screw.
            3) The hydronic kit will be provided with a flush line connection to ensure lubrication at the seal face and allow for positive venting of the seal chamber.
            4) Each port shall be fitted with an isolation valve that allow the units to operate in parallel or standby, yet may be used to isolate one pumping unit for servicing or removal with the other pump still running.
            5) Pump shall be rated for 150 psig (1034 kPa) working pressure.
            6) The pump case shall have gage tappings at the suction and discharge nozzles and include drain ports.
            7) Dual pumps shall allow for the servicing of one pump without draining the chilled water loop.
            8) Motors shall totally enclosed 3-phase type with grease lubricated ball bearings.
            9) Each pump shall be factory tested per Hydraulic Institute Standards.
            10) Pump motors shall be VFD compatible.
        iv. Pressure/temperature taps (3) shall be factory installed to measure the pressure differential across the pump and across the strainer.
        v. Combination valve (which includes check, isolation, and modulation) shall be factory installed. Pressure/temperature taps (2) shall be factory installed to measure the pressure differential across the combination valve.
        vi. Hydronic assembly shall have factory supplied electric freeze protection to –20 F (–29 C).
        vii. Piping shall be Schedule 40 black steel.
        viii. Cast iron or ductile iron body strainer with 8 mesh screen. A factory-installed, removable fine mesh clean-out strainer for initial run period shall be included.

13. Special Features:
Certain standard features are not applicable when the features designated by * are specified. For assistance in amending the specifications, contact your Carrier representative.
    - Low Ambient Temperature Head Pressure Control:
    - Unit shall be capable of running at outdoor ambient temperatures down to –20 F (–29 C) with the addition of antifreeze in the cooler circuit, wind baffles, and field-installed or factory-installed solid-state low ambient temperature head pressure control with condenser coil temperature sensor.
    - Unit-Mounted Non-Fused Disconnect:
    - Unit shall be supplied with factory-installed, lockable, non-fused electrical disconnect for main power supply.
    - Optional Condenser Coil Materials:
        i. E-coated microchannel coils: E-coated aluminum microchannel coil shall have a flexible epoxy polymer coating uniformly applied to all coil external surface areas without material bridging between fins or louvers. Coating process shall ensure complete coil encapsulation, including all exposed fin edges. E-coat shall have a thickness of 0.8 to 1.2 mil with top coat having a uniform dry film thickness from 1.0 to 2.0 mil on all external coil surface areas including fin edges. E-coated coils shall have superior hardness characteristics of 2H per ASTM D3363-00 and cross hatch adhesion of 4B-5B per ASTM D3359-02. Impact resistance shall be up to 160 in./lb (ASTM D2794-93). E-coated coil shall have superior impact resistance with no cracking, chipping, or peeling per NSF/ANSI 51-2002 Method 10.2.
        ii. Aluminum fin/copper-tube coils:
        Coil shall be constructed of seamless copper tubes mechanically bonded to aluminum fins. fins shall have wavy enhancements. These condenser coils are recommended with remote cooler applications. These coils are not recommended for corrosive environments.
        iii. Pre-coated aluminum-fin coils:
        Shall have a durable epoxy-phenolic coating to provide protection in mildly corrosive coastal environments. Coating shall be applied to the aluminum fin stock prior to the fin stamping process to create an inert barrier between the aluminum fin and copper tube. Epoxy-phenolic barrier shall minimize galvanic action between dissimilar metals.
        iv. Copper-fin coils:
        Shall be constructed of copper fins mechanically bonded to copper tubes and copper tube sheets. Galvanized steel tube sheets shall not be acceptable. A polymer strip shall prevent coil assembly from contacting sheet metal coil pan to minimize potential for galvanic corrosion between the coil and pan. All copper construction shall provide protection in moderate coastal applications.

v. E-coated aluminum-fin coils:
Shall have a flexible epoxy polymer coating uniformly applied to all coil surface areas without material bridging between fins. Coating process shall ensure complete coil encapsulation. Color shall be high gloss black with gloss — 60° of 65-90% per ASTM D523-89. Uniform dry film thickness from 0.8 to 1.2 mil on all surface areas including fin edges. Superior hardness characteristics of 2H per ASTM D3363-92A and cross hatch adhesion of 4B-5B per ASTM D3359-93. Impact resistance shall be up to 160 in./lb (ASTM D2794-93). Humidity and water immersion resistance shall be up to minimum 1000 and 250 hours respectively (ASTM D2247-92 and ASTM D870-92). Corrosion durability shall be confirmed through testing to no less than 3000 hours salt spray per ASTM B117-90. Coil construction shall be aluminum fins mechanically bonded to copper tubes.

vi. coated copper-fin coils:
Shall have a flexible epoxy polymer coating uniformly applied to all coil surface areas without material bridging between fins. Coating process shall ensure complete coil encapsulation. Color shall be high gloss black with gloss — 60° of 65-90% per ASTM D523-89. Uniform dry film thickness from 0.8 to 1.2 mil on all surface areas including fin edges. Superior hardness characteristics of 2H per ASTM D3363-92A and cross hatch adhesion of 4B-5B per ASTM D3359-93. Impact resistance shall be up to 160 in./lb (ASTM D2794-93). Humidity and water immersion resistance shall be up to minimum 1000 and 250 hours respectively (ASTM D2247-92 and ASTM D870-92). Corrosion durability shall be confirmed through testing to no less than 3000 hours salt spray per ASTM B117-90. Coil construction shall be copper-fins mechanically bonded to copper tube sheets. Galvanized steel tube sheets shall not be acceptable. A polymer strip shall prevent coil assembly from contacting sheet metal coil pan to maintain coating integrity and minimize corrosion potential between the coil and pan.

vii. Remote Enhanced Display:
Unit shall be supplied with indoor-mounted, remote, 40-character per line, 16-line display panel for field installation.

viii. Medium Temperature Brine (080-350 only):
Unit shall be factory modified to start and operate at leaving chilled fluid temperatures below 30 F (–1.1 C).

ix. Energy Management Module:
A factory or field-installed module shall provide the following energy management capabilities: 4 to 20 mA signals for leaving fluid temperature reset, cooling set point reset or demand limit control; 2-step demand limit control (from 0% to 100%) activated by a remote contact closure; and discrete input for “Ice Done” indication for ice storage system interface.

x. Condenser Coil Trim Panels:
Unit shall be supplied with field-installed coil covers.

xi. BACnet Communication Option:
Shall provide factory installed communication capability with a BACnet MS/TP network. Allows integration with i-Vu® Open control system or a BACnet building automation system.

xii. BACnet Translator Control:
Unit shall be supplied with factory or field-installed interface between the chiller and a BACnet Local Area Network (LAN, i.e., MS/TP EIA-485). Field programming shall be required.

xiii. LON Translator Control:
Unit shall be supplied with factory or fieldinstalled interface between the chiller and a Local Operating Network (LON, i.e., LonWorks FT-10A ANSI/EIA-709.1). Field programming shall

xiv. Navigator™ hand held portable display:

1) Portable hand held display module with a minimum of 4 lines and 20 characters per line, or clear English, Spanish, Portuguese or French language.
2) Display menus shall provide clear language descriptions of all menu items, operating modes, configuration points and alarm diagnostics. Reference to factory codes shall not be accepted.
3) RJ-14 connection plug shall allow display module to be connected to factory-installed receptacle.
4) Industrial grade coiled extension cord shall allow the display module to be moved around the chiller.
5) Magnets shall hold the display module to any sheet metal panel to allow hands-free operation.
6) Display module shall have NEMA 4x housing suitable for use in outdoor environments.
7) Display shall have back light and contrast adjustment for easy viewing in bright sunlight or night conditions.
8) Raised surface buttons with positive tactile response.

xv. Touch Pilot™ display:
Unit shall be supplied with a field-installed, remote-mount, touch screen display for network attachment to the chiller.

xvi. Compressor Suction Service Valve:
Standard refrigerant discharge isolation and liquid valves enable service personnel to store the refrigerant charge in the cooler or condenser during servicing. This factory-installed option allows for further isolation of the compressor from the cooler vessel.

xvii. Suction Line Insulation:
Insulation is tubular closed-cell insulation. This option is required with the medium temperature brine option and recommended for areas of high dewpoints where condensation may be a concern.

xviii. Service Option:
The service option provides a remote service port for Navigator™ connection and a factory-installed convenience outlet that includes 4-amp GFI (ground fault interrupt) receptacle with independent fuse protection. Convenience outlet is 115-v female receptacle. Service option not available with 380 v.

xix. Remote Service Port:
Shall be a field-installed receptacle for Navigator device connection.

xx. Wye-Delta Starter:
Unit shall have a factory-installed, wye-delta start to minimize electrical inrush current.

xxi. Control Transformer:
Unit shall be supplied with a factory-installed transformer that will allow supply control circuit power from the main unit power supply.

xxii. GFI Convenience Outlet:
Shall be factory or field-installed and mounted with easily accessible 115-v female receptacle. Shall include 4 amp GFI receptacle.

xxiii. Plus-One-Pass Cooler:
Unit shall be equipped with plus-one-pass cooler heads to be used with low temperature brine options or high delta T application.

xxiv. Minus-One-Pass Cooler:
Unit shall be equipped with minus-one-pass cooler heads with reduced water-side pressure drop for series flow dual chiller control or high chilled water flow applications.

xxv. High Ambient Temperature:
Unit shall be equipped with high speed condenser fan motors to improve performance at high ambient temperatures. This option shall be required for 30XA400-500 chillers which are operating in multi-chiller configurations or have ambient temperatures at or above 100 F (37.8 C).

xxvi. Security Grilles:
Unit shall be provided with factory (or field) installed painted grilles to protect the condenser, cooler and compressor.

xxvii. Upper Hail Guard:
Unit shall be equipped with a factory-installed option consisting of louvered panels on the ends of the machine which firmly fasten to the machine frame. These panels shall cover the unit from the top to the bottom of the coils, thus providing protection of the coils from hail damage.

xxviii. Full Hail Guard:
Unit shall be equipped with field-installed accessory consisting of hinged, louvered panels, which cover both ends of the unit. This accessory provides complete protection from hail.

xxix. Full End Screen:
Unit shall be equipped with a factory-installed option consisting of louvered panels that cover the machine ends from top to bottom and firmly fasten to the machine frame. These end screens function as a privacy screen and also provide hail protection.

xxx. Low Sound Package:
Unit shall be provided with sound attenuation package to include sheet metal enclosures with sound absorbing panels for each compressor.

xxxi. Remote Cooler Kit:
Allows remote installation of the cooler.

xxxii. Minimum Load Control:
Unit shall be equipped with microprocessor-controlled minimum load control that shall permit unit operation below the minimum standard operation (varies by unit size).

xxxiii. External Pump Control:
This field-installed accessory shall be required to provide control of dual, external pumps. This accessory shall not be required for single, external pumps or factory-installed pumps.

xxxiv. Dual Chiller Accessory Kit:
For dual chiller applications, unit shall be provided with the additional hardware (thermistors, wells, connectors) required for proper system operation.

xxxv. Vibration Isolation (Field Mounted):
Neoprene Isolators - 1 Inch Deflection Spring Isolators: Level adjustable, spring and cage type isolators for mounting under the unit base rails.
2 Inch Deflection Seismic Isolators - Level adjustable, restrained mounts in rugged welded steel housing with vertical and horizontal limit stops. Housings shall be designed to withstand a minimum 1.0 g accelerated force in all directions to 50 mm

C. Chilled Water Pumps SET

The chilled water pumps shall be horizontal, base mounted, centrifugal, end suction pumps.

The impeller shall be made of copper alloy, statically and dynamically balanced and mounted on a stainless steel shaft.

The pump shall have mechanical seal and shall be connected to the motor with a flexible coupling.

The motor shall be a three phase squirrel cage, induction motor.

Each pump shall be guaranteed to circulate at least the nominal discharge of water under the existing head without overheating the motor of the bearings.

Each pump shall be supplied complete with all necessary accessories and mainly :

- Suction and discharge shut-off valves, discharge check valves and fittings.
- Pressure gauges and gauge cocks at both inlet and outlet.
- Strainer
- Vibration isolator mounting with flexible connections.
- Common base plate for the pump and the motor.

Pump sets shall be :

- Bolted and grouted to concrete bases.
- Aligned after being attached to bases. Alignment procedure shall provide accurate and proper angular, and concentric relationship of motor and pump shaft by use of shims tapered dowels through bolted connections.
- Have piping connections arranged so that the pump casing is not subjected to forces by the piping

The Contractor shall supply and install an electric panel board for chilled water circulating pump including:

- The main disconnecting switches
- All necessary starters and controllers with alternate operation for pumps.
- On/Off default pilot light
- Auto manual switch
- Magneto-Thermal protection for each pump.

D. Expansion tank

Supply and install expansion tank wherever shown on the drawings and as specified herein:

Closed type, including an interchangeable nitrogen bag tested to 7 bars at 110°C.

Horizontal or vertical closed vessel. One piece Butyl moduled bladder, fixed inside the vessel in one or two points. Bladder provides a complete separation between air and water, and is protected by filter.

Internal and external anti-corrosion paint.

AIR HANDLING (15850)

A. Ductwork

Supply and install all ductwork as shown on the drawings and specified herein.

Ducts shall be constructed of galvanized steel sheets conforming to ASTM A 526-71, galvanized by the hot-dip process coating designation G90 or approved equivalent standard. Minimum weight of zinc coating (total on both sides) 275 g/m^2.

Ductwork shall be installed in accordance with ASHRAE or SMACNA requirements for low pressure ducts.

Ductwork sheets thicknesses shall conform with the following table:

Duct	Largest Dimension inches (cms)	US Gauge	or mm
Up	to 12" (Up to 30)	26	0.60
13"	to 30" (31 to 75)	24	0.70
31"	to 42" (76 to 105)	22	0.90
43"	to 54" (106 to 135)	22	0.90
55"	to 84" (136 to 210)	20	1.00
85"	to 120" (211 to 300)	18	1.30

Ducts used for kitchen exhaust shall be black steel 3mm thick.

Ductwork shall be installed complete with:

a. Metallic supports, seams, joints, bracings and fixing accessories.

b. Flexible canvas connections between ducts and air handling equipment (fans, air handlers, fan coil units, etc...).

c. Elbows, splitters, vanes and access doors as per ASHRAE or SMACNA requirements.

d. Connections and fixings to air outlets.

e. Wood frames for air outlets fixings and ducts passages through walls and slabs.

f. Insulation and/or vapour barrier wherever specified.

g. Acoustic lining wherever specified and/or indicated on the drawings.

Flat ducts over 18" wide shall be stiffened by cross breaking; however, if duct is made one gauge thicker than required for its size, cross breaking may be omitted.

Horizontal ducts shall be supported from ceilings by means of trapeze type hangers consisting of a 5cms x 5cms x 5mm thick angle iron 10cms longer than the duct width on either side. The angle shall be hung from the ceiling by means of two 10mm round steel rod hangers with threaded ends bolted through the angle with nuts and washers. The rods shall be attached to the ceiling by means of 20mm masonry expansion bolts. Horizontal exposed ducts shall be neatly supported with a round supporting galvanized iron flat bands and round galvanized steel rod hangers.

Vertical ducts shall be supported from the floor or side by means of 5cms x 5cms x 5mm thick angle iron riveted to the ducts and extended to rest on the floor or on similar angles cast in the wall.

Supports shall not be attached to ducts by means of sheet metal screws.

Maximum spacing of duct supports for horizontal ducts shall be as follows:

Duct Largest Dimensions (inches)	Maximum Spacing of Duct Supports
up to 30"	2.4 m

31" to 54"	1.8 m
> 54"	1.2 m

Vertical ducts shall be supported at every storey height.

All parts outside and inside ducts which are visible to the outside through air outlets shall be painted with a matt black colour paint.

All exposed ducts and their supports shall be painted with one coat of primer suitable for galvanized steel and two coats of finishing paint of type and colour as approved by the Engineer.

B. Plenums and Boxes

Supply and install all plenums and duct boxes wherever shown on the drawings and as specified herein.

Unless specifically mentioned otherwise on the drawings, plenums and boxes construction and installation shall be similar to ductwork.

C. Flexible Canvas Connections

Supply and install all flexible canvas connections wherever shown on the drawings and as specified herein.

a. Flexible canvas connections shall be flame proof material, fabricated from chemically impregnated canvas.

b. Connections to air handling equipment (fans, air handlers, fan coil units, etc,... shall be by means of special bands or clamps which can ensure adequate air tightness.

c. The free section of the flexible connections shall be not less than 15cms and not more than 30cms.

Supply and install all air outlets wherever shown on the drawings or specified with the various air handling equipment.

Unless specifically mentioned otherwise, each air outlet shall be constructed of extruded anodized aluminum and painted to the colour as approved by the Engineer.

1. Grilles and Louvers
   Each grille shall be complete with:

   a. Double deflection blades for supply and return grilles and fixed blades for exhaust grilles , transfer grilles and louvers.

   b. Fixing frame for outlet mounting on walls, doors, ducts, false ceiling, etc... Frame may be of wood or metallic construction as site conditions dictate.

   c. All necessary supports and fixing accessories for concealed fixing.

   d. The grilles and louvres shall be power coated.

   Louvers Specifications shall be identical to the grilles except that they shall have fixed inclined blades of storm proof construction. Each louver shall be provided with a non corrodible insect screen mesh.

   Fixing shall be of the concealed type without screws.

2. Fan Coil Unit Supply and Return Grilles

   Fan coil unit supply grilles: double deflection type with individually adjustable horizontal face bars and vertical rear bars.

   Fan coil unit return grilles installed on same wall as unit supply grille shall be same size and shape as supply grille.

Fan coil unit return grilles installed in false ceilings shall be fixed blade type with blades set at 45° deflection parallel to long dimension. Grille net free area shall be not less than 70% of gross face area.

Fixing shall be of concealed type with no screws.

3. Door Grilles

Each door grille shall be square or rectangle shape and complete with:

a. Inverted "V" or "Y" fixed type horizontal blades.

b. Fixing frame for outlet mounting on doors on both sides. Frame may be of wood or metallic construction as site conditions dictate.

c. All necessary supports and fixing accessories.

Door grilles shall be installed with bottom at a uniform height of 40 cms above floor level.

E. Fire Dampers

Supply and install fire dampers on all ducts crossing the structural slabs, as shown on drawings and as specified herein.

Fire dampers shall be provided in ducts, walls, or floors, where shown on the drawings, and of detail as shown thereon.

Fire dampers shall be constructed of 3mm thick black steel plate, with frames and blade so designed as to cause no obstruction to air flow when in the open position. Fire dampers shall be rated at 2 hour fire resistance. Fire dampers shall be installed without strain or distortion to any part and all moving parts shall move freely without building. Dampers shall be caulked tight around the frames which shall extend the full thickness of wall or floor in which they are installed.

Fire dampers shall be weighted so that they will close promptly when released regardless of pressure and direction of air flow. The damper blade shall be hung on zinc-coated steel hinges with loose fitting brass pins and bushings. It shall close tightly against angle stops and shall have retaining springs.

The damper blade shall be held open by a fusible link having a melting temperature of not higher than 75° C (167° F). An access door shall be provided in the duct for replacement of the fusible link.

F. Sound Attenuators

Supply and install sound attenuators on all air handling equipment to satisfy the required noise level criteria whether or not shown on drawings and as specified.

a. Sound attenuators shall be suitable for 100 mm W.G. internal air pressure and 40 deg. C operating air temperature. Maximum static pressure drop through silencer is not to exceed 5 mm W.G. at specified air quantity. Silencer to attenuate sound by at least 10 DB in the 125 Hz and 30 DB in the 2000 Hz octave band mid-frequencies respectively.

b. Sound attenuators for axial flow fans: shall be the product of fan manufacturer, designed to match fan with end rings drilled and tapped to match fan flanges. Silencer shall be cylindrical type with centre pod, comprising galvanized steel casing lined with mineral wool and retained by expanded steel. Lining shall be rot proof and fire proof faced to withstand high air velocities without erosion.

Sound attenuators shall have specially designed sound absorbent single or double pods mounted concentrically within lined outer casing. It is shall be complete with lifting lugs and mounting feet of same type supplied for fan.

c. Sound attenuators for air handling units: straight, rectangular, splitter type, designed for mounting in ducts, with pre- drilled flanges. Silencer is shall have number of air passages in parallel and in height and width to meet resistance to air flow requirements and length to meet sound attenuation requirements.

Sound attenuators to comprise multiple galvanized steel splitters held in galvanized steel casing. Splitters and casing shall be lined with rot-proof and fire-proof resin bonded mineral wool faced with woven glass fibre.

G. Centrifugal Fans

Supply and install all centrifugal fans wherever shown on the drawings and as specified herein.

Fans shall be V-belt driven, suitable for floor mounting and shall be complete with:

a. Heavy structural steel housing, wheel, drive and supports. Single width, single inlet or double width, double inlet as shown on drawings.

b. Silent type, centrifugal wheel statically and dynamically balanced, backward inclined blades.

c. Totally enclosed fan cooled electric motor designed for a maximum speed of 1450 rpm, with built-in motor overload protection.

d. Adjustable base for electric drive motor.

e. Heavy duty bearings, grease lubricated, self aligning, pillow block, ball or roller type, on both sides of the fan wheel.

f. Duct connecting flanges and gaskets.

g. Flexible canvas connections connecting fan with associated ductwork.

h. Vibration isolation structural steel base with spring isolators and supports.

j. Adjustable V-belt drive with belts and guard.

k. Additional features and accessories required for its installation and satisfactory operation.

Capacity and type of each centrifugal fan shall be as given in the schedules of capacities and/or the Bills of Quantities.

H. Axial Fans

Supply and install all axial fans wherever shown on the drawings and as specified herein.

Axial fans shall be suitable either for panel or frame mounting or for duct mounting as conditions may require.

Each axial fan shall be complete with:

a. Silent propeller blades statically and dynamically balanced.

b. Totally enclosed, fan cooled motor with built-in overload protection and a maximum speed of 950 rpm.

c. Heavy gauge steel housing, mounting flanges and gaskets.

d. Motor starter and isolating switch.

e. Flexible canvas connections connecting fan with associated ductwork whenever provided.

f. Additional features and accessories required for its installation and satisfactory operation.

Capacity and type of each axial fan shall be as given in the schedules of capacities and/or the Bills of Quantities.

J. Propeller Fans

Supply and install propeller fans as specified herein:

a. Wall mounting type, supplied complete with electric motor, pressed steel ring mounting plate, wire guard on motor side, discharge louver shutters with aluminum frame.

b. Steel blades, statically and dynamically balanced .

c. Heavy duty ball bearing, prelubricated with high quality lithium base grease.

L. Fan Coil Units

Supply and install fan coil unit wherever shown on the drawings and as specified herein.

Basic unit to consist of water coil, one or more centrifugal fans, electric motor, condensate drain pan, galvanized steel casing panels, filter, electric junction box and fan switch. Unit shall be suitable for both chilled and hot water.

Water coil: staggered 12.7mm O.D. heavy wall seamless copper tubes mechanically bonded to aluminum fins, with 15mm solder joint copper tube connections and manual air vent. Coil shall be leak tested at factory to 24 bars (350 psi) minimum air pressure under water.

Basic unit casing: 18 gauge galvanized steel sheet braced and reinforced for maximum rigidity, thermally and acoustically insulated with fiberglass blankets fastened with waterproof adhesive.

Centrifugal fans: forward curved, non-overloading type, directly connected to fan motor, statically and dynamically balanced and designed for whisper quiet operation. Materials shall be high strength and corrosion resistant.

Motor: split capacitor, 3-speed type, with built-in thermal overload protection and bronze sleeve type bearings with oil reservoirs. Motor shall be resiliently mounted.

Condensate drain pan: 18 gauge galvanized steel extended type specially constructed, projecting under entire length and width of coil including headers and return bends, valves and fittings. Pan shall be treated against corrosion, insulated and pitched for positive drainage with unit installed level.

Fan switch: 3-speed with 'OFF', provided with each unit from factory. Decorative wall plate remote type for horizontal units. Unit mounted and prewired type for vertical units.

Horizontal concealed unit: basic unit complete with four rubber grommets for ceiling mounting and isolation and with return filter plenum consisting of mixing box forming integral part of unit, bottom access and 25mm thick cleanable aluminum filter.

Vertical concealed unit: basic unit complete with sub-base for floor mounting with levelling adjustment, secondary condensate pan, permanent, cleanable, aluminum air filters with provision in unit casing for easy removal of filters.

Vertical cabinet unit: basic unit complete with decorative cabinet constructed from cold rolled, heavy gauge sheet steel, bonderized, coated with baked enamel finish and thermally and acoustically insulated. Cabinet shall have stamped discharge grille on top, return air opening on bottom an two access doors on either side for easy manipulation of controls and air vent. Unit shall have removable single piece front panel to give complete access to internal components.

M. Air handling units

Supply and install air handling unit wherever shown on the drawings and as specified herein.

M1 General

- Each unit consist of fan, motor, V-belt drive, cooling and/or heating coils as required, drain pan, filters and necessary controls.
- The unit shall be either mounted on a suitable base, or hung from the ceiling. In all cases approved vibration eliminators shall be provided. The Contractor shall submit details of bases, mountings and connections to the Engineer for approval.
- The unit(s) shall be of the draw thru Low/medium pressure type.
- The contractor shall confirm to the Engineer the total static pressure of the fan after the Engineer's approval on the air handle and after preparing the shop drawings.

M2 Construction

- Air handling unit shall be constructed of a heavy gauge galvanised steel with removable panels for accessibility to all internal parts.
- Unit(s) shall be factory insulated internally with fiberglass 40mm, thick or approved equivalent and finished with oven dried grey finishing coat.

M3 Fan section

- The fan section shall be constructed of heavy gauge sheet steel properly reinforced and braced with steel angle framework. It shall be provided with suitable angle flanges for connecting it to the coil section.
- Fan shall be centrifugal type with multi-blade forward curved or air foil type, mounted on a common shaft with enclosed housing. The fan motor shall be statically and dynamically balanced to eliminate noise and vibration.
- Fans bearings shall be grease lubricated ball type with grease lines extending to the outside surafce of the casing. Average life of bearing shall not be less than 200000 hours.
- Fan shall conform to the design fabrication of the AMCA.
- Fan shall be mastic coated and have galvanised steel wheel and high grade steel shaft.
- Fan shall be driven by V-belt of variable pitch type. Belt guards of removable type shall be provided on the fan and motor shafts.
- The electric motor starter and controllers shall be in accordance with the Electrical section of these specifications.

M4 Coils

- The coil shall be suitable for chilled and/or hot water application.
- The coil shall be of seamless copper tubing, having aluminum fins mechanically bonded to the tubes.

- The headers shall be of seamless copper with supply and return connections. Each header shall be provided with drains and vents.
- The coil shall be tested at not less than 250psig (1725 Kpa).
- The face velocity shall not exceed 550 FPM (2.8m/s).
- The coil shall be accessible for service and shall be removable without dismantling the entire unit.

M5 Filter section

- The air filter section shall consist of prefilter and final filter stages. Pressure drop in the filter when dirty shall not exceed ½" WG (125 pa). Filters shall be easily removable for cleaning.
- Filters shall be provided with rigid self supporting corrosion resistant steel frames and clamps, gasketed and sealed to prevent air bypass.

M6 Drain pan

- An insulated drain pan shall be provided in each unit under both the fan and the coil section.
- Drains pans shall have drain connections on both sides and a deep seal trap.
- Drain pan shall be suitably connected to the drainage system.

N. Air handling units for operating theaters

N1 General

The Contractor shall supply and install central station air handling units, double skin, draw-through, vertical or horizontal type as indicated, complete with fan, electric motor, V-belt driver, cooling coil, heating coil, air filters, necessary control and accessories as shown on the drawings. Capacities are as indicated on the drawings.

N2 Construction

Shall be double skinned, sectionalized, comprising fan section, coil section and specified accessories as specifically designed by manufacturer for unit. Fan and coil section casings and accessory casings shall be heavy gauge, mill galvanised formed steel panels adequately braced and reinforced for maximum rigidity. Casing panels to removable for easy access to internal components.

N3 Casing

Factory fabricated acoustic panel casings, double skin 0.5mm thick galvanised outer and inner sheets, a "Penta Post" supporting frame. Panels and frames are shall be secured using internally bolted fixings so that welding minimized and integrity of the galvanised finish is maintained. Panels are shall be provided with 25mm thick fiberglass filter and shall be designed to withstand an internal positive pressure of 250mm water gauge in the outlet section and an internal negative pressure of 75mm water gauge in the fan inlet section.

Casing shall be fitted with quick release doors. All panels are shall be screwed on external side to permit removal of components through either side of unit. Casing shall be self supporting on 3mm horizontal span or 3.6mm vertical span.

N4 Coating

Casing panels are shall be pre-coated externally and internally with 10 microns of primer and 200 microns of plastisol topcsart.

N5 Insulation

All sections shall be thermally and acoustically insulated with 25mm thick, 41kg/m^3 density, neoprene coated fiberglass insulation secured to internal surface of casing panels with waterproof adhesive and permanent fasteners.

N6 Fan section

Shall have one or more centrifugal fans, with BI blades, mounted and keyed on common heat-treated, ground and polished solid steel shaft. Shaft shall be supported on self aligning pillow block regreasable ball bearings. Fan wheels and scrolls to bonderized steel painted with baked enamel or unpainted mill galvanised steel.

N7 Inlet guide vanes

Shall be provided where indicated in the schedule of equipment, in both inlets of fan and shall be installed within the inlet bells. Vane operating shafts shall be connected to control ring by crankarms. Both sets of vanes shall be operated by a lever on the fan scroll with connecting shaft between inlets. Operating of inlet vanes shall be means of a pressure controller.

N8 Motor

Totally enclosed, squirrel cage, introduction type, mounted on adjustable bracket securely supported on internal framing of fan section with minimum class F insulation. Once a motor fails to start an alarm signal is shall be activated at the operator console.

N9 Drive

To comprise fan pulley, adjustable motor sheave, V-belt, belt guard and provision for belt tensioning adjustement.

N10 Coil section

Shall have heavy duty coil tracks extending full width to support coils throughout their length and to provide easy removal of coils from coil connections side of casing. Condensate drain pan of double wall construction is to extend under whole coil section, fixed to it and adequately pitched to amply sized threaded drain connections on both sides. Pan shall be treated against corrosion and adequately insulated and vapour sealed between outer and inner walls. Stacked cooling coils shall have intermediate drain pans with drop tubes at either end to drain into main drain pan.

N11 Coil construction

Shall be removable cartridge type constructed of heavy wall seamless copper tubes bonded to aluminum fins by mechanical expansion and staggered in direction of air flow. Coil shall be leak tested at factory to 2410 Kpa minimum air pressure with coil submerged in water. Coil face area is not to exceed 2.5 meters per second coil face velocity at specified air quantity. Coil shall have number of rows and fins per cm to satisfy required capacity at specified condition, with not more than 5 fins per cm.

N12 Chilled water and hot water coil

Shall have galvanised steel casing and steel headers treated against corrosion. Coil shall be mounted in coil section shall be free draining and continuously vented with non-air trapping circuits. Headers and U-bends shall be within casing. Coil shall have vent and drain fittings on each header. Number of circuits shall be such that water velocity satisfies specified conditions without exceeding specified maximum water pressure drop through coil. Water velocity through tubes is not to exceed 1.8 meters per second and not less than 0.76 meter per second.

N13 High velocity filter section

Shall be bolted to coil section inlet, complete with access doors for easy removal of filters from either side and with required number of high velocity, 50mm thick, permanent, cleanable, aluminum air filters.

N14 Bag filter section

Shall be standard double skinned, bag section provided with stiffener bars for rigidity, with double skinned, down stream access door, provided with compartment lifting. Bag filter media 550m thick, fire resistant finer, fibred all glass medium 80-90% dusty spot efficiency to ASHRAE 52-76, combined to corrosion resistant framing, section shall be provided with hanging clips bulkhead light and glass inspection panel.

N15 Dampers Leakage Rate

Do not exceed the following for a pressure differential between the up-stream part and down-stream part of damper of 100 pa when damper is closed.

Number of modules :

Leak (m^3/hr)	1	2	3	4	5	6	7	8
	130	260	390	520	650	780	910	1040

N16 Accessories

Access doors shall be double skinned, gasketed air tight to ASTM 1056-79 and provided with heavy hinges and quick release catches. All service and inspection doors shall be mounted flush, sheatheed to match the unit siding. Doors to open against the air pressure.

N17 Vibration isolators

Shall be provided on all air handling units and shall be spring type, free standing and laterally stable without any housing and complete with 6mm neoprene acoustical friction pads between the base plate, and the support. All mountings shall have leveling bolts that must be rigidly bolted to the equipment. Spring diameters shall be not less than 0.8 of the compressed height of the spring at rated load. Springs shall have minimum additional travel to solid equal to 50% of the rated deflection.

N18 Controls

1. General
   Operation rooms' HVAC control system shall be made up to the highest standards so that it will provide proper and completely separate control of the space temperature and humidity conditions of each operating room up to the surgeon set conditions. The Contractor shall provide all sensors and control devices required for proper operation and to the satisfaction of the Engineer.

2. Control general description
A central controller of the DDC type (direct digital controller) shall be provided at the air handling units room to control the primary circuit (air handling unit) and the secondary circuits at each operating room (hot water coilsheater & electric humidifier),
DDC shall be equipped with a fixed operator terminal to control and monitor the various HVAC conditions of the operating room as herein below described.

3. Control sequence

a. Primary circuit (AHU)

Temperature and humidity sensor located in the supply air duct shall sense the supply air temperature and humidity level and shall send a signal to the direct digital controller (DDC) which will compare it with the temperature and humidity level set points and it will control the cooling coil 3 way motorized valve and the heating coil 3 way motorized valve to achieve the required air conditions.

In case the supply air (SA) humidity level is greater than the preset conditions, the DDC will set the AHU for dehumidification mode and it will overcool and reheat the air so that the SA temperature and humidity reaches the preset level.

Differential pressure switches shall be provided for every filter bank stage, which will relay the DDC whenever the pressure drop in the filter bank reaches the preset level. The DDC will actuate an audible and visual alarm to indicate dirty filter condition.

Smoke detector installed in the supply air duct (SAD) shall detect smoke in the duct and shall relay the DDC to de-energise the air hanlder fan and initiate audible and visual alarm, also it will send a signal to the main fire alarm control panel (if available).

b. Secondary circuit

Individual temperature and humidity remote set points shall be provided at each operating room to set the required operating room temperature and humidity levels. The set points shall be connected to the DDC which will control the secondary circuit elements.

Temperature and humidity sensors located in the room exhaust air duct branch shall sense the temperature and humidity level and shall relay the DDC to control the current valve of the duct heater (if heating the air is required), and to control the humidifier (if humidification is required) to meet the individual room set points.

A flow switch is provided at the secondary circuit to sense the air flow, which will be connected to the DDC, the DDC shall forbid the energization of the secondary electric heater in case of zero flow.

Smoke detector is provided and connected to the DDC to stop the primary supply air fan in case of smoke detection and to initiate an audible and visual alarm at the main panel and at the surgeon panel.

A differential switch is provided for the room absolute filter and connected to the DDC to indicate dirty filter, (whenever it reaches the preset level), on the main panel and on the surgeon panel.

The DDC shall measure the room temperature and humidity and shall indicate the conditions at the surgeon panel.

The surgeon panel of every operating room shall house the following:

- Temperature setting point
- Humidity level setting point
- Room temperature digital indicator
- Room humidity level digital indicator
- Room filter (clean/dirty) indicator
- Room pressure (+ve/-ve) indication (described under room pressurization below).

c. Operating room pressurization

A pressure transmitter shall be provided in each of the dirty and clean corridors of the operating rooms.

Also one pressure transmitter shall be provided for every operating room.

The DDC shall compare the pressure levels in each of the operating rooms and the adjacent clean and dirty rooms and shall indicate (+ve) or (-ve) pressure of each room at the main panel and at each relevant surgeon panel. If (-ve) pressure is detected, audible alarm must be initiated in addition to the visual indication.

4. Digital controller

a. Hardware

Digital plant Control processors (PCPs) shall be 16 bit microprocessor types with EPROM OS and EEPROM or flash memory for all data file and control programs. PCPs shall have internal real -time clocks with a minimum of 72 hours battery backup power up to 30 days capacity.

PCPs shall be provided where shown or specified with capacity to accommodate input/output (I/O) points required for the application plus spare points specified.

These panels shall be configured with analog and digital inputs and outputs, and pulse counting totalizers and such that the input , the output and all control logic shall be resident in a single microprocessor to provide stand-alone closed loop DDC. Each panel shall have as a minimum 12 universal (field selectable as analog or digital) inputs and 12 universal outputs. Analog configurated outputs shall be true variable voltage (0-10v) for driving analog devices. Analog outputs shall have a minimum incremental resolution of one percent of the operating range of the controlled device. Each panel shall be provided with a socket for a Portable Operators Terminal (POT), or note book PC.

PCPs shall have LEDs for continuos indication of power and operational status. PCPs shall also have LEDs to indicate the status of each digital input and each output (analog output LEDs shall be variable intensity). Each output shall have an associated on-off auto or open-closed-auto switch. All LEDs and swiches shall be visible without opening the panel door, but not accessible without opening the panel door.

All panel electronics shall be installed in suitable enclosures. Equipment room panels shall have hinged doors and shall also contain all load relays, transducers, and associated equipment.

b. Control software

Each PCP shall contain up to 20 unique user modifiable time programs (TP).

Each TP shall consist of daily, weekly, and annual programs plus a "Today" temporary function.

Daily programs shall be definable for day types such as working day, half day, holiday, weekend, etc. Each daily program shall allow a list of time based (or optimum time based) analog and digital commands shall be issued to user selected plant elements and points.

Weekly programs shall allow a user selected set of daily programs shall be defined for each of the week (Monday through Sunday)

The annual program shall initially be an automatic compilation of 52 weekly programs. Selecting a date of the annual program shall allow modification of the daily selection entered into the weekly program (such as changing Dec. 25 from a working day to holiday).

Control application Software shall be customized strictly to meet the detailed requirements of the "Sequency of Operation" specified hereinafter. PCPs shall be fully programmable. Initial software shall be fully modifiable , and not restricted by vendor's specific configuration guidelines. All PCP control software shall be designed via graphic programming facility, the detailed graphic design of which shall be provided as system documentation. All control strategies shall be advanced as noted with stabilizing setpoint ramps and procedures to assure slow loading of variable load equipment.

c. Management Software

1. Each PCP shall be provided with a trend archive of least the last 200 events (digital transitions or analog value changes) of any user selected group of up to 20 points. A stored event shall include date and time, and value or status. Events occurring in excess of 200 shall overwrite the oldest events, except where a modern module is specified, events shall be uploaded to the modern module. Pointy events shall be displayable on the POT as trend logs for evaluation of control system performance.

2. Each PCP shall monitor all analog input points and specified digital points for off-normal conditions. Each alarm shall have an "alarm delay" attribute which shall determine how long (in minutes/seconds) a point must be in an off-normal state prior shall being considered in an alarm state. Alarms shall be displayable on the POT.

d. Operator's Terminal Panel

1. General

A fixed liquid crystal display and entry key board, (or note book PC), shall be provided for operator readout of systems variables, override control, and adjustment of control parameters at all PCPs and for all TECs shall display points with English - language descriptions.
The terminal panel shall be complete with command keys, data entry keys, cursor control keys, and a liquid crystal alpha- numeric display. Access is shall be via self - prompting menu selection with next menu/previous menu and step forward/step backward within a given menu.

Displays shall provide text via a 64 - character minimum screen with unique English descriptors for each specified physical and pseudo point.

2. Terminal Functionality
Terminal functionality shall include :

   a. Display for :
      - Space temperature
      - Local set point value (Degrees °F)
      - Mode : Occupied/Unoccupied
      - Mode : Heating/Cooling
      - Actual CFM primary air
      - Fan status
      - Heating status
      - Zone override status
      - Room pressurization level
      - Filter condition
      - All other required as described before.

   b. Display and command for :
      - Dry bulb and relative humidity
      - Setpoint select (local/remote)
      - Allowable local setpoint mid-range
      - Allowable local setpoint range
      - Unoccupied setpoint - cooling humidity level
      - Unoccupied setpoint - heating
      - Deadband for heating
      - Proportional band heating
      - Proportional band cooling
      - Proportional bank hummdification
      - Integral gain cooling
      - Integral gain heating
      - Derivative gain heating
      - Derivative gain cooling
      - all other required as described before.

3. Terminal panel minimum Functionality shall be as follows :

   a. Terminal panel shall allow the user to display software information, and via password control, modify PCP software. Two levels of user controlled passwords shall be provided. The first level shall allow the user to modify, create, or delete time programs, and the second level shall allow the user to modify data point text descriptors, reset totalizers, modify setpoints and parameters, set the system clock, and view trend logs alarms.

   b. Selecting Data Points from the top level menu shall initiate an interactive process to select any point via English menu, select manual or analog commanding of the point, select a display of equipment accumulated runtimes, select a historical trend log display of any trended point, or display all points whose alarm capability has been suppressed and allow the suppression shall be canceled.

   c. Selecting Parameters from the top level menu shall initiate a scrolling of all PCP parameters (such as alarm units, control settings, etc.) which may be displayed and commanded.

d. Selecting Alarms from the top level menu shall present a menu of four alarm display options. selecting Alarm Memory shall scroll a list of all alarms in memory with English descriptor, alarm value or status, alarm type (low alarm limit, etc.), and time of occurrence. Selecting Points in Alarm will produce a similar display of all points currently in alarm. selecting Critical Alarms shall display critical points currently in alarm. selecting Non-Critical alarms shall display non-critical points still in alarm.

e. Selecting Trend LOG from the top level menu shall initiate a scroll selection bar of English descriptors of all points being trended, and allow selection of trend values/events with date and time of each historical occurrence.

f. Selecting System Clock from the top level menu shall allow the user to modify the calendar/time clock and enter a date for automatic change to/from daylight savings time.

O. HEPA Filter

Supply and install HEPA filter in line of fresh air duct related to operating rooms as shown on the drawings and as specified herein :

- Effi ciency MPPS 99,95 % - EN 1822:2009 classifi cation H13- Final pressure drop 600 Pascals
- Maximum operating temperature 70 °C
- Maximum relative humidity 100 % CE mark ATEX version
- Nominal air flow rate ;as shown on drawings and bill of quantities
- type absolute filters of the highest filtering surface.
- Frontal air speed : 2.5 - 3 m/s
- Galvanized steel frame Filter to have a special expanded polyurethane single piece gasket.
- Modulo housings can be used for duct or wall filtration systems.
- Shall have a very flexible systems easy to install, made of galvanized steel sheet and have an access door with handle and wheel fi xing,fitted with a closed cell neoprene gasket on door ledge.The filter is locked using an eccentric lever. Perforated flanges with M8 threaded inserts are positioned at air inlet/outlet.

R. Energy Recovery Fresh Air Handling Units

R1 General

Energy Recovery Ventilator shall be listed per ANSI/UL 1995, Heating and Cooling Equipment. Energy transfer ratings of the energy recovery wheel shall be ARI Certified. Performance shall be as scheduled on plans. Exhaust discharge and outside air intake shall not be located on the same side on roof top units.

R2 Unit Casing and Frames

Unit shall be of internal frame type construction of galvanized steel. Frame and panels shall be G90 galvanized steel. All panels exposed to the weather shall be a minimum of 18 gauge galvanized steel. Unit shall be internally lined with galvanized sheet metal creating a double wall. Where top panels are joined there shall be an overlapping, standing seam to insure positive weather protection. All metal-to-metal seams shall be factory sealed, requiring no caulking at job site. Permatector exterior finish is available for outdoor units.

Unit base to be designed for curb mounting. Unit base shall overhang the curb for a positive seal against water run-off.

R3 Weatherhoods

Weatherhoods shall be the same finish as the unit. Outdoor air weatherhood shall incorporate a louvered design and moisture eliminator. Weatherhoods shall be tested in accordance with AMCA Standard 500-L and achieve an 'A' water penetration classification rating up to 8 in/hr rainfall at 50 mph.

R4 Insulation

Unit casing to be insulated with 2-inch fiberglass. Insulation shall meet requirements of NFPA 90A and tested to meet UL 181 erosion requirements. Insulation to be enclosed in double wall construction.

R5 Energy Recovery Wheels

Wheels shall be of the enthalpy type for both sensible and latent heat recovery and be designed to insure laminar flow. Energy transfer ratings must be ARI Certified to Standard 1060 and bear the ARI certification symbol for ARI Air-to-Air Energy Recovery Ventilation Equipment Certification Program based on ARI 1060. Ratings "in accordance with 1060" without certification are not acceptable. Desiccant shall be silica gel for maximum latent energy transfer. Wheel shall be constructed of lightweight polymer media to minimize shaft and bearing loads. Polymer media shall be mounted in a stainless steel rotor for corrosion resistance.

Wheel design shall consist of removable segments for ease of service and/or cleaning. Silica gel desiccant shall be permanently bonded to wheel media to retain latent heat capability after cleaning. Wheels with sprayed on desiccant coatings are not acceptable. Wheels with desiccant applied after wheel formation are not acceptable. Energy recovery device shall transfer moisture entirely in the vapor phase.

Energy recovery drive belt material shall be high strength urethane and shall be factory installed in a pre-stretched state, eliminating the need for field belt tension adjustment. Link style belts are not acceptable.

R6 Access Doors

All components shall be easily accessible through removable doors for exhaust, supply, filter, and damper compartments. Energy recovery wheels shall have ample access for ease of inspection, removal, and cleaning.

R7 Roof Curbs

Roof curb to be supplied by unit manufacturer for field assembly. Curb shall consist of die formed galvanized steel sections. Curb shall be full perimeter type with gasketing provided for field installation between curb and unit base.

R8 Fan Sections

Plenum supply fan to be non-overloading, airfoil style, centrifugal type. Bearing supports shall be constructed of welded structural steel members to prevent vibration and to rigidly support the fan shaft and bearings. The fan wheel shall be of the non-overloading centrifugal type. Wheels shall be statically and dynamically balanced to balance grade G6.3 per ANSI S2.19. The wheel cone and fan inlet cone shall be carefully matched and shall have precise running tolerances for maximum performance and operating efficiency. Turned, precision ground and polished steel shafts shall be sized so the first critical speed is at least 25% over the maximum operating speed for each pressure class. Close tolerances shall be maintained where the shaft makes contact with the bearing. Bearings shall be heavy duty, grease lubricated, self-aligning ball or roller pillow block type. Bearings shall be selected for a minimum life (L-10) of 80,000 hours at maximum operating speed and horsepower for each construction level. Each assembled fan shall be test run at the factory at the specified fan RPM and vibration signatures shall be taken on each bearing in the horizontal, vertical, and axial direction. The maximum allowable fan vibration shall be 0.150 in/sec peak velocity, filter-in reading as measured at the fan RPM. Fans shall be licensed to bear the AMCA Seal for sound and air performance.

Centrifugal exhaust fans to be double width, double inlet, forward curved type. Blower wheels shall be statically and dynamically balanced. Ground and polished steel fan shafts shall be mounted in permanently lubricated, sealed ball bearing pillow blocks. Bearings shall be selected for a minimum (L10) life in excess of 100,000 hours at maximum cataloged operating speeds. Separate motors for exhaust and supply blowers shall be provided. Adjustable sheaves on belt-driven fans with motors less than 10 hp shall allow independent balancing of exhaust and supply airflows. Fan and motor assemblies are mounted to unit base with neoprene isolators as standard. Fans shall be located in draw-through position in reference to the energy recovery wheel.

R9 Motors and Drives

Motors shall be energy efficient, complying with EPACT standards, for single speed ODP and TE enclosures. Motors shall be permanently lubricated, heavy-duty type, matched to the fan load and furnished at the specified voltage, phase, and enclosure. Drives shall be sized for a minimum of 150% of driven horsepower. Pulleys shall be of the fully machined cast type, keyed and securely attached to the fan wheel and motor shafts; 10 horsepower and less shall be supplied with an adjustable drive pulley. Energy wheel motors shall have integral overload protection.

R10 Filters

Supply and exhaust air filters shall be 2-inch thick pleated fiberglass, 30% efficient and tested to meet UL Class 2. Filter racks shall be die-formed galvanized steel.

R11 Electrical

All internal electrical components shall be factory wired for single point power connection. Units with electric reheat will be wired with independent power supply. All electrical components shall be UL Listed, Approved, or Classified where applicable and wired in compliance with the National Electrical Code.

Weatherproof, integral door interlocking disconnect switch, motor starters, control circuit fusing, control transformer for 24 VAC circuit, and terminal strip shall be supplied as standard components in the control center. Motor starters consist of a contactor and Class 20 electronic adjustable overload protection and shall be provided for all motors in the unit.

R12 Cooling Coil

Direct expansion (DX) and chilled water coils shall be factory tested and rated in accordance with ARI 410. Coils shall have copper tubes with permanently expanded aluminum fins, 12 fpi or less. DX coils shall be equipped with distributors to receive expansion valves at the liquid connections.

R13 Warranty

The energy recovery ventilator shall be warranted to be free from defects in material and workmanship for a period of one year from the purchase date. The energy recovery wheels shall be warranted to be free from defects in material and workmanship for a period of five years from the purchase date. Motors shall be warranted by the motor manufacturer for a period of one year

S. Vacuum and Compressed Room Acoustical Insulation System

Supply and install vacuum and compressed room acoustical insulation system wherever shown on the drawings and as specified herein :

The vaccum and compressed air room shall be acoustically insulated to respect acceptable sound levels specified 15005 - J1, in all adjacent spaces.

- Room access door shall be acoustical
- All room walls shall be acoustical.

CONTROLS AND INSTRUMENTS (15950)

A. General Requirements

Controls and instruments are mentioned and specified under each system or equipment shall be provided in this Contract. This section covers only general conditions and requirements shall be implemented for control and instruments.

Controls and instruments shall be supplied and installed wherever specified and/or shown on the drawings and shall conform with the followings:

a. All controls, relays, switches, gauges, instruments, floats, etc,... necessary for the satisfaction operation of each system or equipment shall be supplied and installed whether specifically mentioned or not.

b. Install control valves horizontally with drive up.

c. Reading instruments and gauges shall be provided with adjustable marker to set normal operating figure.

d. Unless specifically mentioned otherwise, controlled, variables shall be maintained within the following limits of the set point:

Temperature :	± 2° F (1° C)
Pressure and Humidity:	± 5 per cent
Water levels	± 3 per cent

e. Where adjustments and calibrations of controls and instruments are specified and/or provided, they shall be installed to allow for access facility.

f. Wall mounted controls and instruments shall be fixed at normal eye-sight level and securely fixed in place in accordance with manufacturer's recommendations.

g. Control voltage shall not exceed 220 volts.

h. Shop drawings submit for approval complete control and wiring diagrams for control systems intended, showing all control instruments, auxiliaries and accessories.

j. Accessories and appurtenances: Provide as necessary and appropriate to accomplish intended control functions, irrespective of whether or not shown or specified, such as switches, relays, transformers or other.

k. Control wiring and conduits: Provide as necessary and appropriate for complete control system and conforming to requirements of Section 15030 Electrical Works for Mechanical Systems. Make all necessary connections to controls and equipment.

l. Indicating instruments such as pressure gauges and thermometers are shall have range such that normal readings are indicated in middle of instrument range.

m. Indicating instruments installed on insulated pipes are shall have necks to extend instrument to final finished insulation surface.

n. Separable socket wells for immersion thermostats and thermometers are shall be brass, threaded and of size and length to suit instrument and pipe.

p. Manufacture: control instruments and appurtenances are shall be the product of one manufacturer, of latest design and as recommended by manufacturer for control systems intended. Controls are shall be supplied for local electric current, unless noted otherwise.

q. Wall mounted thermostats: install 1.5m above floor level on inside wall and where temperature at thermostat is not affected except by room temperature.

r. Immersion thermostats and thermometers shall have bulbs inserted in brass separable socket wells installed vertically or at an angle. Socket wells are shall be installed through female threaded steel fittings welded to pipe. Insertion depth is to suit pipe.

s. Controls shall be electrical or electronic type as indicated.

B. Calibrations and Adjustments

After completion, controls and instruments shall be calibrated and adjusted to ensure that systems controlled or monitored by them operate satisfactory and in conformity with the Specifications and their intended functions.

Whenever controls and instruments complexity dictates, the Contractor shall provide, at his expenses, an Engineer from the Manufacturer for calibrations and adjustments.

C. Temperature Controllers

1. Room Thermostat: to provide line voltage, on-off control of fan coil unit valve and fan through spdt switching having the following features:
   - wall mounted, with silver bronze finish and moulded cover
   - manual fan speed and on/off selection (on/off -lo-med-hi)
   - horizontal temperature scale range with set point control lever
   - provision to break cooling circuit when fan is off
   - range approximately 40-90 deg. F with fixed differential of 2 deg. F
   - accessories including outlet box and adjustable range stops.

2. Return Air Duct Thermostat and Temperature Controllers: to provide line voltage, proportional control of damper or valve motor through sensing element and capillary adjusting potentiometer in proportion to temperature variations having the following features:
   - set point adjustment knob on dial
   - differential adjustment dial with 135 ohms resistance potentiometer
   - liquid filled, fast response coiled capillary element for duct applications or sensing bulb with immersion well components for chilled and heating water pipes applications
   - 6 meters copper capillary tube
   - range 55-175 deg. F with adjustable proportioning range of 3-30 deg. F
   - accessories including controller mounting, capillary holder for mounting sensing element in air duct or immersion well assembly with compression fitting and tube clip for mounting bulb in tank or with T-strap for clamping bulb on pipe.

3. Low Limit Thermostat and Temperature Controller Type T-3: to provide line voltage, on-off control of damper or valve by sensing temperature of air in duct or liquid through an spdt switch. Type having the following features:
   - set point adjustment knob on dial
   - differential adjustment dial with snap-acting switch
   - liquid filled, fast response coiled capillary element for duct applications and sensing bulb with immersion well components for pipe applications

- 6 meter copper capillary tube
- range 55-175 deg. F with adjustable differential of 3-10 deg. F
- accessories including wiring knock-outs, controller mounting, capillary holder for mounting sensing element in air duct with bag assembly or immersion well assembly with compression fittings and tube clip for mounting bulb in tank or with T-strap for clamping bulb on pipe.

D. Motorized Valves and Actuators

1. Motorized Valves : line voltage, 3-way, 2-position type providing diverting control of water flow through solenoid motor actuator in response to signal from spdt controller. Valves having the following features:
   - all brass, with flare fitting ends
   - integral motor-actuator removable from valve body without draining system
   - manual opener for operation on power failure
   - rated 125 psi, 200 deg. F maximum water temperature, 125 deg. F maximum ambient temperature, opening or closing time 30 seconds
   - accessories including end-switch enclosure.

2. Motorized Valves: low voltage, 3-way, mixing, proportional reversing type, providing modulating control of water by-pass flow through operation of motor actuator and valve linkage in response to signal from proportional controller. Valve having the following features:
   - valves 1/2" to 2" sizes, with two inlets and one outlet screwed end connections, cast bronze body, stainless steel stem, brass plug, integral brass seat and spring loaded, self-adjusting, Teflon cone packing
   - valves 2 1/2" and larger, with two inlets and one outlet flanged end connections, cast iron body, stainless steel stem, brass plug, replaceable bronze seat and spring loaded, self-adjusting, Teflon cone packing
   - reversing type motor, oil-immersed gear train, die-cast aluminum case, single 160 degree stroke, double-ended crankshaft, die-cast aluminum cover with built-in transformer and direct drive feedback potentiometer
   - linkage directly mounted on motor, without adjustment requirements and comprising roller, slide mechanism, cam and stem position indicator and with 150 lb. seal-off force
   - valve rated 250 deg. F maximum water temperature and 150 psi maximum water pressure
   - motor rated 125 deg. F maximum ambient temperature.

E. Sequence Controllers

1. Sequence Controller: to provide sequence control for multiple water chiller units or multiple boiler units according to the preset temperatures and provide programmed permutations for lead / lag chillers or boilers for equal use.
   Advanced proportional plus derivative microprocessor control algorithm, with the required number of steps for 3 water chiller units and for 2 water boiler heating units. Shall be used with electronic temperature sensors.

F. Sensors

1. Temperature Sensor

   To provide proportional single output for electronic temperature controller. Type having the following features:

   electronic type

   insertion or immersion type for mounting on air duct or liquid line

   set point range -40 to + 257°F

   accessories including 125 to 450mm insertion element for duct mounting and 100mm immersion element with pressure rating for 150 psi for liquid line mounting.

2. Humidity Sensor -

   To provide proportional or proportional plus integral control action, electronic type. Range 15-90% RH with adjustable throttling range 1-10% RH.

3. Flow Switch

   To shut off water chiller when water flow through chiller drops to preset quantity. Type similar to McDonnel and Miller model FS 4-3 or approved equal and having the following features:

   pedal vane type with single-pole, double-throw contacts

   flow sensitivity adjustment.

G. Instruments

1. Thermometer

   Mercury in glass type, minimum 6 inch long, with brass protective cover and brass separable socket well and graduated in Fahrenheit with 2°F divisions. Obtain from one of the following:

2. Pressure Gauge

   Bourdon tube type, minimum 100mm dial diameter, with flangeless back and 12.7mm male threaded bottom connection and graduated in PSI with 2 PSI divisions. Gauge shall have black finished cast aluminum case, threaded black epoxy cast aluminum ring with gasketted glass face, type 316 stainless steel spring tube, stainless steel precision movement and micrometer adjustment on needle.

MEDICAL GAZ INSTALLATION (15960)

General

All works detailed should be carried out by a company, or under the direction of a company, with ISO accreditation to ISO 9001: 1994 Quality Assurance Schedule for:

- The Design, Manufacture, Supply, Installation, Commissioning and servicing of Industrial and Medical Pipelines and Distribution Systems for use with gases.
- Supply, Installation and Commissioning of Associated Plant and Alarm Systems for use with the above, including the associated electric wiring.

A copy of above mentioned certificate should be presented.

All works will be completed with the minimum disruption to existing services and shall be in strict accordance with the medical gases permit to work.

After completion of works a compliance certificate should be submitted. The company that will carry out the testing and commissioning must be certified to do such work. A copy of the permit must be presented. All expenses for such a company shall be paid by the contractor.

A. Medical compressed air plant

A. General

The compressed air plant shall be of modular construction and designed so that all

major components are at least of duplex configuration.

Air shall be provided by air plant capable of providing a net flow-rate (F.A.D.) as described in the schedule of capacities with one pump not running and after dryer losses. The plant shall consist of two identical air compressors and one receiver and a duplex filter/dryer module.

B. Standards

The air compressors shall be of proven reliability and shall be driven by electric motors to Class F insulation and noise levels tested to BS 4999. The receiver vessel shall be constructed and tested to EN 286 or BS 5169 / 1975 Class 3 Grade E. The control panels and electric installations shall conform to the latest IEE regulations and the starters are to BS 4941.

C. Air Compressors

A total of two identical single stage reciprocating air compressors shall be provided each directly driven by an electric motor and incorporating an air inlet filter and silencer. Each compressor shall be provided with air-blast after-coolers and auto/manual drains. The compressor electric motors shall be squirrel cage type suitable for a 380 volt ac three phase 50 Hz supply - with a DOL starter.Capacity as shown on the schedule of equipment

The air compressor, after-cooler and control circuitry must be mounted on a single skid.

The compressor should be oil lubricated, single stage reciprocating type. The unit must incorporate a high volume fan, cooling ring, after-cooler. Air inlet filter and a silencer. The compressor must have the additional benefit of requiring an oil change every 2000 hours or twelve months whichever is the shortest period.

A separate fused 3 phase supply is required for each compressor.

Each after-cooler is operated by an air blast from a motor driven fan. The after-cooler assembly includes an automatic drain with manual by-pass and forms part of the compressor control assembly. Additional components are also mounted on the after-cooler framework: the dump solenoid valve and silencer, fail to load pressure switch, temperature switch, non-return valve, isolation and safety valves.

D. Receiver Vessel

One No. Vertically mounted welded steel receiver vessel shall be provided with an access panel to enable full internal inspection . the total vessel capacity will be as shown on the schedule of equipment. The receiver shall be protected by a pressure relief valve and fusible plug. Which melts if combustion should take place either internally or externally to the receiver. The receiver is fitted with an automatic drain with manual bypass to remove moisture / condensation.

E. Filter Dryer Assembly

Air delivery must be via a duplexed sets of filters; pre-filter, oil filter, dust filter, activated carbon filter and bacterial filter. Each filter shall be fitted with differential pressure gauges to monitor filter performance.

The air shall contain no more than:

–	Water		$115mg/m^3$
–	Dry Particulate		$0.01mg/m^3$
–	Oil mist	<	$0.01mg/m^3$
–	Oil vapor		$<0.03mg/m^3$
–	Carbon monoxide		$5.0mg/m^3$ 5ppm v/v
–	Carbon dioxide		$450mg/m^3$ 500ppm v/v

Duplex desiccant dryers shall incorporate a dew point alarm system.

Each dryer must have a double absorber, are heat-less and filled with activated alumina desiccant. The absorbers are automatically reactivated on a timed cycle.

The high specification of the dryer means that it will perform equally well in temperate as well as hot climates.

The modules must also incorporate the dump valves and silencers. All maintenance, including desiccant changes can be done in-situ.

The dryer operation must be completely automatic with full control from its own dedicated, easy to read, control panel. The control panel must have individual failure indication if either a high dew point fault or low pressure fault occurs. In this event the standby dryer must be automatically selected and an alarm condition initiated.

The dryer control panel must be linked to the central control panel to ensure no purge losses in a non-demand situation. In the event of a power failure to the dryer all solenoids open to maintain a supply of air to the distribution system.

The dryer control panel can be programmed to give purge cycles suitable for any climate. A "fast forward" feature enables the dryer cycle shall be checked in seconds.

All filters and dryers must be duplexed and the system must be with non-return valves and ball valves to carry out filter changes without affecting the supply of air to the hospital.

F. Control Panels

A dedicated control panel shall be provided, for each air compressor, to house the isolating switch, starter, MCB, ammeter, hours run meter, lead compressor selection switch, pressure switch, alarm and BMS contacts.

Under normal conditions the capacity of the plant shall be 100% system design flow with one compressor not running. A pressure transducer shall sense the pressure and operate logic circuits within the control panel to switch the lead compressor on or off, maintaining the design flow. A digital readout of vessel pressure shall be located on the central control panel door capable of being switched to show pressure in Kpa, psi or bar. During periods of peak demand the lag air compressor shall automatically be activated to operate in addition to the lead compressor.

The compressor shall automatically shut down once pressure levels have been restored. In the event of a lead compressor failure, the lag compressor shall take over and the first stage of the remote alarm system shall be activated. In the event of all compressors failing the second stage remote alarm shall be activated by the control panel. Should the primary control circuit fail an independent system with a separate mechanical back-up switch will operate the compressors and also initiate a plant fault alarm.

The air plant shall have four stages of alarm conditions inputting to the alarm system as follows:

1. Plant faults caused by: Control circuit failure. Activation of any other safety device or failure of a selected compressor to run up to speed on time.
2. Plant Emergency caused by: Low receiver pressure fault (0.5 bar below cut-in pressure of the lag compressor or 0.5 bar above cut-out pressure of the lead compressor). Dew point above -26°C at atmospheric pressure.
3. Reserve fault caused by: Reserve manifold pressure less than 50%.
4. Pressure fault caused by: Low pipeline or high pipeline pressure.

Building Management Systems contacts shall be: (Normally Open or Normally Closed Contacts)

Plant Fault, Plant Emergency, Reserve Fault and Pipeline Pressure Fault.

G. Plant Central Control Unit

The central control panel should automatically matches the demand with selection and rotation of the lead pump. A transducer controls the cut-in, cut-out settings for the lead and lag compressors and has a mechanical back-up in the event of a malfunction. The central controller can operate up to four pumps so the plant capacity can be field expandable at a later date. An electronic watchdog monitors the central processor and will indicate a plant fault in the event of a malfunction. For additional safety all voltages within the central control panel must be less than 30 volts.

H. Motor Control Unit

Each pump must be fitted with a dedicated motor control unit. This incorporates a three phase and neutral isolator, ammeter, motor circuit breaker, starter, hours run meter, pressure switch and indicating LED's for the following pump status:

a. Normal
b. Control circuit failed

c. Overload tripped
d. Failed to go on load
e. After-cooler temperature high
f. Running
g. Power on
h. Hand control
i. Auto control

The digital pressure readout can be set in Kpa, psi or bar on site. The control panels must be simple to maintain and to fault find. The central control unit must houses the main PCB, transducer, mechanical back-up switch and LED indication for the following:

a. Power on
b. High demand
c. Compressor status; lead, running and failed
d. Vessel pressure level in Kpa, psi or bar
e. Auto or manual selected

Plus the following alarm condition:

a. Normal
b. Plant fault
c. Plant emergency
d. Reserve cylinders low
e. Pipeline Pressure fault

No-volt normally closed contacts must be available for the above conditions, in addition Normally Open (N/O) or Normally Closed (N/C) BMS contacts must be also available for conditions (b) to (e).

H. Motor Control Unit (cont'd)
In addition to BMS connections in each starter:

a. Control circuit failed
b. Overload tripped
c. Failed to go on load
d. After-cooler temperature high

B. Medical vacuum plant

A. General

Medical vacuum shall be provided by vacuum plant capable of providing a flow-rate shown on the schedule of equipment, of free air aspired at a vacuum of 450mm hg (gauge) with one pump not running. The plant shall consist of two identical vacuum pumps and one receiver.

B. Standards

The vacuum pumps shall be of proven reliability and shall be driven by electric motors to Class F insulation and noise levels tested to BS 4999. The receiver vessel shall be constructed and tested to EN 286 or BS 5169/1975 Class 3 Grade E. The control panels and electric installations shall conform to the latest IEE regulations and the starters are to BS 4941. The bacterial filter element guarantees bacterial removal to 0.005% when tested to BS 3928 at full hospital design flow. Drainage trap bowls and bacteria filter bowls shall be suitable for sterilization. The Medical vacuum plant must be capable of maintaining a vacuum

of at least 300mm Hg at the connection point of each terminal unit with a flow of 40 l/min whilst operating at system design flow.

C. Vacuum Pumps

The vacuum pumps shall be air cooled, oil flooded rotary vane directly driven by a 380 volt, three phase 50 Hz electric motor. The pump inlet shall be filtered and the exhaust shall incorporate an oil filter. Each vacuum pump and associated pipe-work shall incorporate non-return valves to protect both the vacuum system and receivers from inadvertent pressurization.

D. Receiver Vessel

One No. floor mounted welded steel receiver vessel shall be provided with inspection access panel and manual drain. The total vessel capacity will be as shown on the schedule of equipment.

E. Bacterial Filter Assemblies

Flow passes through a duplex system of bacterial filters fitted with manual isolating valves to permit duty and standby operation. Each bacterial filter must have a replaceable element and fitted with a sterilisable moisture drainage bowl with isolating cock and differential pressure indicator. When the indicator reads 100 mbar the element needs changing. The system ensures bacterial removal to 0.005% when tested to BS 3928 at full hospital design flow. The pressure drop through a clean filter passing the system design flow rate will not exceed 25 mm Hg.

F. Control Panels

A dedicated control panel shall be provided, for each vacuum pump, to house the isolating switch, starter, MCB, ammeter, hours run meter, hand/auto switch, vacuum switch, alarm and BMS contacts. Under normal conditions the capacity of the plant shall be 100% system design flow with one pump not running. A transducer shall sense the vacuum level and operate logic circuits within the central control panel to switch the lead pump on or off, maintaining the design vacuum level. During periods of peak demand the lag vacuum pump shall automatically be activated to operate in addition to the lead pump.

The pump(s) shall automatically shut down once vacuum levels have been restored. In the event of a lead pump failure, the lag pump shall take over and the first stage of the remote alarm system shall be activated. In the event of all pumps failing the second stage remote alarm shall be activated by the control panel.

Should the primary control circuit fail an independent system with a separate mechanical back-up switch will operate the pumps and also initiate a plant fault alarm. The vacuum plant shall have three stages of alarm conditions inputting to the alarm system as follows:

1. Plant Faults caused by:
   - Control circuit failure.
   - Activation of any other safety device or failure of a selected pump to run up to speed on time.
2. Plant Emergency caused by:
   - Low receiver vacuum (50mm Hg above cut-in pressure of the lag pump(s).
3. Pressure Fault caused by
   - Pipeline vacuum less that 360mm Hg.

Building Management System contacts shall be:

(Normally Open or Normally Closed contacts)

Plant Fault, Plant Emergency, Pipeline Pressure Fault.

G. Plant Central Control Unit

The central control panel must automatically match the demand with selection and rotation of the lead pump. A transducer controls the cut-in, cut-out settings for the lead and lag pumps, as well as the low vacuum alarm. Mechanical back-up in the event of a malfunction is a must.

The central controller must be capable to operate up to four pumps so the triplex module package plant capacity can be field expandable at a later date.

An electronic watchdog to monitor the central processes is a must and will indicate a plant fault in the event of a malfunction. The central control panel must contain only 12 volts dc.

The central control unit must house the main PCB, transducer, mechanical back-up switch and LED indication for the following:

a. Power on
b. High demand
c. Pump status; lead running and failed
d. Vacuum level in mm Hg
e. Auto or manual selected

Plus the following alarm conditions:

a. Normal
b. Plant fault
c. Plant emergency
d. Pipeline pressure fault

No-volt normally closed contacts must be available for the above conditions, in addition Normally Open (N/O) or Normally Closed (N/C) BMS contacts must be also available for conditions (b) to (d).

H. Motor Control Unit

Each pump must be fitted with a dedicated motor control unit. This incorporates a three phase and neutral isolator, ammeter, motor circuit breaker, starter, hours run meter, vacuum switch and indicating LED's for the following pump status:

a. Normal
b. Control circuit failed
c. Overload tripped
d. Failed to go on load
e. Running
f. Power on
g. Hand control
h. Auto control

In addition BMS conditions:

a. Control circuit failed
b. Overload tripped
c. Failed to go on load

C. Manifold systems

A. Main Supply Manifolds

The manifold system shall incorporate a one piece control panel, manufactured from a solid construction using latest RTM epoxy technology in GRP molding with a hinged form panel to facilitate easy maintenance. The unit shall be suitable to withstand extreme temperatures without any degradation or weakening. All internal wiring shall be 12V DC for safety purposes, with the PCB connected with plug and socket connections for easy maintenance. It shall enable fully automatic operation, selecting duty and standby banks by automatic detection, the unit will be provided with a manual change over button so that the duty and standby banks can be selected manually. The manifold control panel shall comprise two stages of regulators suitable for a flow rate of 0 - 2000 l/m at 7 bar (whilst maintaining a pressure of +/- 0.5%). For Oxygen and Nitrous Oxide the manifolds shall be set at a distribution pressure of 4.1 bar. Pressure relief valves for both intermediate and final pressure shall be capable of passing the total maximum flow and both systems shall be piped to atmosphere. A by-pass valve shall be installed for decompression and commissioning purposes with the vent piped directly into the relief valve exhaust.

The header assembly shall be wall mounted each cylinder shall be connected to the header by means of a flexible cupro-nickel tailpipe. The header shall be fitted with a non return valve for each tailpipe and be gas specific to prevent tailpipes for other gases being fitted. The header shall fit directly to the control panel with a high pressure mechanical connection.

The manifold will have the capability of transmitting signals into the main alarm system as follows:

1. Change Cylinders: This condition will occur when either the left or right hand bank (the automatically detected duty) is empty and the manifold has changed over to the other bank (standby).
2. Change Immediately: The second condition will be activated when the standby bank has been depleted (both banks empty).
3. Reserve Fault: Will be activated when the level of the gas in the emergency standby manifold has fallen to 50% capacity.
4. Pressure fault: Caused by a pressure fluctuation on the main supply from the manifold (line pressure) of any greater than +/- 10 - 15%.

B. Emergency Standby Manifold

Each main supply manifold shall have an emergency standby manifold (ESM) fitted to manually take over the supply of gas in the event of emergency or total manifold replacement. The ESM will be fitted with he same tailpipes as the main manifold.

The pressure in the cylinders shall be monitored by a high pressure switch which will relay a signal to the main control panel in the event of a reduction in pressure to 50% normal (Oxygen and Air) or 90% normal (Nitrous Oxide). This signal shall be displayed on the Main Manifold Control Panel and be retransmitted into the main alarm system.

Each manifold will be supplied with support racks with cylinder retaining chains, headers and tailpipes for both duty and reserve banks, as well as a spare rack for wall mounting with retaining chains to hold cylinders for the duty bank.

C. Capacities

Oxygen will be supplied from a 2 X 5 manifold complete with Manifold Control System (MCS) Panel & 2 cylinder emergency supply manifold (ESM).

Nitrous Oxide will be supplied from a 2 X 2 manifold complete with MCS panel & 2 cylinder ESM.

Emergency Air supply at 4. bar and 7 bar will be supplied from a 2 X 2 cylinder ESM.

D. Labeling and Location

All MGPS accommodation should be clearly labeled as to their purpose. For example, cylinder stores should be labeled with the type of cylinders contained. Details of emergency action procedures and location of keys should be posted, as should no smoking and other warning signs such as no parking sign (in the vicinity of the delivery and storage areas). Separate clearly identified bays should be provided for full and empty cylinders which are shall be stored in racks. Separate areas for different categories of gases should be provided, but it is not necessary to construct a physical barrier unless it is convenient to do so. Adequate means of securing cylinders to prevent falling should be provided.

All manifolds, including the emergency reserve manifolds may be located within the same room and should not be in the same room with medical air compressors or vacuum plants.

D. Alarm system

Two alarm systems shall be used, the Central Alarm System for plant and supply equipment monitoring, and a Local Area Alarm System for monitoring the condition of gas down stream of the final isolation valve.

A. Main Alarm System

The main alarm system shall have a capacity for 5 gases with each gas display capable of displaying normal and 4 fault conditions. In general the conditions will be as mentioned in the plant and manifold systems as detailed above, and legends will be pre-printed as standard.

The alarm panel shall display flashing lights corresponding to the fault in question together with an audible signal. The alarm fault can be accepted at the panel at which time the flashing light will steady and the audible alarm shall mute. If the cause of the fault is not corrected within 15 minutes the alarm system will reset and the flashing lights and audible signal will resume.

In the event of long term shut downs or faults with plant the alarm can be set to accept the existing faults as a maintenance item. As soon as the maintenance "fault" has been normalized, the alarm will automatically reset to normal operation.

All system alarm cabling between the alarm panels, and between alarm panels and plant or manifolds, shall be monitored so that the system can detect a wiring fault, open or short circuits. This fault shall be displayed on the alarm panel as a "system fault" and the panel will be to detect in which area the fault exists and the type of fault.

Main alarm panels shall be positioned at the following locations:

1. Plant Room
2. Manifold Room
3. Telephone Switchboard

B. Local Area Alarm System

The local alarm panel shall have a capacity of up to 5 gases with each gas display capable of displaying normal and 2 fault conditions. As standard the conditions will be Normal, High Pressure and Low Pressure, and legends will be preprinted as standard.

The alarm panel shall display flashing lights corresponding to the fault in question together with an audible signal. The alarm fault can be accepted at the panel at which time the flashing light will steady and the audible alarm shall mute. If the cause of the fault is not corrected within 15 minutes the alarm system will reset and the flashing lights and audible signal will resume.

In event of long term shut downs or faults with plant the alarm can be set to accept the existing faults as a maintenance item. As soon as the maintenance "fault" has been normalised, the alarm will automatically reset to normal operation.

All system alarm cabling between the alarm panels and pressure switches, shall be monitored so that the system can detect a wiring fault, open or short circuits. This fault shall be displayed on the alarm panel as a "system fault" and the panel will be able to detect in which gas the fault exists and the type of fault.

Area alarm panels shall be positioned downstream of the final area valve service unit or line in each department.

E. Area valve service units (AVSU)

The AVSU shall be positioned at the entrance to each ward or department and shall provide a zone isolation facility, for use either in an emergency or for maintenance purpose. A physical barrier (spade) shall be capable of insertion when required on either side of the valve, without the need to totally dismantle the line valve. The ZSU shall be fully gas specific, permanently labeled to identify the medical gas service and shall incorporate a gas specific Non Interchangeable Screw Thread (NIST) connection on each side of the valve. Pressure gas services (not vacuum) NIST connections shall incorporate 100% self sealing valves which are normally held closed by gas pressure.
The line valve shall be a brass 22 or 42mm ball valve with PTFE seal/seats, operated by a quarter turn handle with a pin to prevent over traveling both directions. The ball valve shall connect by 22 or 42mm stub pipes to the distribution system (for 22mm connections, at either top, bottom, side or rear entry pipes).

The assembly shall be housed in a self extinguishing ABS valve box which shall be capable of both surface or concealed installation. The whole of the ZSU shall be mounted on a stainless steel back-plate.
The valve box shall incorporate a hinged lid which opens through 180 degrees, to provide maximum access. The hinged door shall be fitted with a glass panel to enable a visual check on the line valve selected position and access in an emergency via a strike button to enable easy shattering of the glass.

The glass itself shall shatter into small pieces so that no sharp edges can cut the operator. The hinged door shall normally be locked closed and ZSU's installed adjacent to each other shall be operated by different key/lock combinations.

The ZSU assembly shall provide for natural ventilation to prevent any localised build up of gas within the valve box.

F. Area service module

The Area Service Module shall be wall mounted or recessed and shall be constructed of internal metal bracket's aluminum framework and extruded aluminum clear anodized sections. Panel shall be manufacture from 9.52mm fire retardant particle board with Formica high pressure laminate backing and facing sheet. Each panel shall be edge-banded with an anodized aluminum extrusion strip, retained by self tapping cadmium plated screws with a snap-in filler and retainer strip. An easily removable panel shall be provided to enable access to the electrical fused connection unit and the pressure/vacuum switch assemblies.

The Area Service Module shall contain a medical gas alarm panel (including pressure switches) and up to five area valve service units (AVSU).

Medical gas/vacuum service shall be fixed copper piped to and from their respective area valve service unit and shall normally terminate in 22mm copper stub pipes connected at ceiling level.

Pressure / vacuum switch assemblies shall be installed as bank mounted on an internal mounting frame and connect to their respective gas service down stream of the area valve service units.

A 3amp fused connection unit shall be provided for the mains electrical power supply. Electrical cable from the connection unit to the medical gas alarm panel shall be and routed and secured clear of the medical gas/vacuum services, and the complete electrical installation shall conform to IEE regulations. All metal components within the module assembly shall be electrically bonded and the installation shall be earthed.

The Area Service Module if shall be wall mounted shall be factory pre-wired, pre-piped, completely assembled and tested ready for installation prior to dispatch. A testing certificate from the manufacturer shall be issued and presented for each area service module before installation. The certificate should be issued by a recognized company to ISO 9001, quality assurance .

The Certificate shall indicate the S/N of the module, S/N of the alarm panel and S/N of the area valve service units, date and place of test along with the name of the tester with his signature.

An operating and maintenance manual shall be provided.

G. Line ball valve assemblies

Medical gas line ball valve assemblies shall be constructed of a nickel plated brass body, PTFE seats/seals and a brass chrome plated ball. The valve shall operate by a manual operating lever selected through 90 deg. All medical gas line ball valves shall provide a full bore flow and shall be cleaned for oxygen service and fully tested prior to dispatch. Smaller valve assemblies (15 to 42mm inclusive) shall incorporate stainless steel 'Dowty' bonded seals and mechanically sealed connectors. Larger valve assemblies (45 to 108mm inclusive) shall be flanged, installed with stainless steel bolts, nuts and spring washers with 3mm Viton sealing gaskets. In all cases, the use of PTFE tape or any other thread sealing medium shall not be used during installation.

Each medical gas line ball valve assembly shall terminate in copper stub pipes to enable brazing direct into the distribution system using the fluxless brazing technique with Nitrogen Purge.

A locking device shall be provided and enable the valve shall be locked in either the fully open or fully closed position.

A certificate of compliance should be presented.

H. Piped distribution system

A. The piped distribution system shall use copper pipes manufactured from phosphorous de-oxidized non-arsenical copper (Grade C106) and be manufactured to metric outside diameters. Pipes are shall be shot-blasted and degreased suitable for oxygen use and cleanliness is shall be maintained by suitable end caps and protective wrapping.

B. Fittings shall be end feed type, manufactured from the same grade of copper as the pipes.

C. Copper to copper joints shall be made on site using a copper phosphorous brazing alloy type CP1 or CP4 using an internal nitrogen inert gas shield without the use of flux. Copper to brass or gunmetal joints shall not be made on site.

D. Pipelines shall be supported at the intervals specified in HTM 2022 using a suitable metallic, non-ferrous material suitably treated to prevent corrosion and electrolytic action. Plastic supports may be used only for the down drops to the terminal units.

E. Medical pipelines should be kept away from areas where they may be subject to any of the following:
   a. Mechanical Damage
   b. Chemical Damage
   c. Excessive Heat
   d. Splashing, dripping or permanent contact with oil, grease or bituminous compounds, electrical sparks,.....

F. Exposed pipelines should not be installed in lift shafts, kitchens, laundries, boiler houses, generator rooms, incinerator rooms, storage rooms designed to house combustible materials or in any other fire-risk area.

G. Pipelines should be protected from the possibility of lightning strikes.

H. Buried pipelines should be run in a trench not less than 450 X 450mm with the pipe protected throughout its length by a continuous glazed earthen wore pipe or carried in properly drained ducts with removable covers. These glazed pipes or ducts should be further protected where the pipe crosses areas used by wheeled traffic. In such areas the glazed pipes and ducts should be encased in concrete. Multi-way ducts should be used where more than one pipe is shall be carried. The route of the pipeline should be identified on the surface and should be clearly shown on site lay out drawings. Pipelines should not be buried solidly in walls or floors, and any joints should be kept to the minimum practicable

J. Identification of pipelines
Pipelines should be identified in accordance with BS 1710 and color banding for the pipelines should be used outside the plant room. Color band identification should be applied near to valves, junctions, walls, etc.. Each gas should be identified in 6mm letters. Self-adhesive plastic or clip-on labels of approved manufacture may be used for this purpose. A band 150 mm wide is usually adequate. All color coded tapes applied by the pipe manufacturers should be removed before the systems are identified in accordance with this paragraph. The direction of flow should be indicated.

J. Terminal units

A. General

Terminal units shall be available as outlets on piped Medical gas distribution systems for the following Medical gas services: Oxygen, Nitrous oxide, Medical air 400 Kpa, Medical air 700 Kpa, and Medical vacuum. Units are gas specific and may be sited in any location within a hospital. Terminal units shall be available for wall or bed head mounting and used in Pendant installations.

B. Standards

The medical gas terminal unit shall conform to international Standard 9170 and the following:

The wall mounted first fix assembly shall consist of a brass pipeline termination block with copper stub permanently secured between a back-plate and a gas specific plate which allows limited radial movement of the copper stub to align with the pipeline. The first fix shall incorporate a maintenance valve (except for vacuum) and a test plug. The test plug provides an effective blank to enable carcass pressure testing. The second fix plastic components shall be molded from fire retardant polycarbonate with the index pin permanently molded into the gas specific socket. The socket assembly retains a capsule assembly, a sealed unit containing the check valve and probe 'O' ring seal. This replaceable capsule assembly enables all working parts subject to wear and tear through usage shall be replaced as a factory tested assembly. Medical gas terminal units shall accommodate variable plaster depth of up to a maximum of 16mm.

Terminal units shall be gas specific and only accept the correct medical gas probe. Gas specific components shall be pin-indexed to ensure that a correct gas specific assembly is achieved so that in the normal course of dismantling for repair or maintenance, parts from other gases cannot inadvertently be used. Wall mounted terminal units shall incorporate an anti-rotation pin to engage with connected downstream medical equipment ensuring correct orientation.

Terminal units shall be designed to allow easy and accurate installation and shall be supplied with installation instructions and a comprehensive Operating and Maintenance manual.

Terminal units installed in pendants shall be attached to their respective flexible hose by a gas specific NIST fitting and anti-rotation pins shall not be fitted.

Terminal units located in a rigid installation shall be capable of single handed insertion and removal of the correct medical gas probe. The terminal units shall have a 3 year warranty, subject to the recommended minimum routine maintenance operations being carried out by correctly competent persons.

C. Description

1. First Fix Assemblies:

   Wall mounted first fix assemblies shall be suitable for surface, concealed, or bed head trunking installations and supplied for either horizontal or vertical pipe entry. With vertical pipe entry, entry may be either from the top or bottom and with horizontal pipe entry, entry may be either from the left or right hand. The first fix assembly consist of a brass pipeline termination block with copper stub pipe, to enable brazing directly to the distribution system using the approved fluxless brazing technique. Each first fix assembly incorporates a plaster box and plaster shield.

2. Multiple Gas Jig Plates:

   To ensure correct alignment and spacing of multiple terminal unit arrays, multiple gas jig plates shall be used to mount the first fix assembly. Jig plate form the foundation for all concealed and if required bed head trunking installations. For ease of installation, multiple gas jig plates are accurately aligned using a purpose built installation jig, and leveling screws enable accurate alignment in both horizontal and vertical planes. With 2 gas service jig plates, a choice of either 133.5mm or 150mm spacing is provided. Multiple gas jig plate dimensions are detailed below:

Jig Plate	Height (mm)	Length (mm)	Chase depth Requirements (mm) (including plaster depth)
2 gas service	95	267	50
2 gas service	95	400	50
2 gas service	95	534	50
2 gas service	95	667	50
2 gas service	95	801	50

3. Second Fix Assemblies:

   Second fix assemblies are gas specific and are suitable for all types of installation. The second fix assembly consists of a gas specific socket and index pin assembly complete with fascia ring, and a capsule assembly. The socket assembly retains the capsule assembly within the first fix and is pin indexed to ensure that the installation is gas specific. The capsule assembly is a sealed unit containing the check valve and probe 'O' ring seal. This design enables all working parts subject to wear through usage shall be replaced as a factory tested assembly, the socket assembly is indexed to accept only the correct Medical gas probe. Probe roller pins inside the socket lock the engaged probe in position which opens the check valve and release is only effected by pushing on the fascia ring. An anti-rotation pin is fitted to all horizontally mounted terminal units to ensure correct orientation of downstream equipment. The terminal unit shall be clearly identified and labeled.

4. Fascia Kit:

   A fascia kit completes the assembly for both surfaces and concealed wall mounted terminal units. The fascia kit accommodates each terminal unit individually and consists of a plastic fascia plate and a bezel. The bezel is used to cover the plaster join and the fascia plate secures the assembly to the gas specific bracket with two countersunk screws.

5. Bed Head Terminal Units:

   Terminal units installed in bed head trunking systems. To ensure correct alignment and spacing, multiple gas jig plates must be installed.

6. Pendant Terminal Units:

   Terminal units installed in Flexible, Rigid, pendants. All these terminal units are identical in operation. In each case the pipeline termination block arrangement is specifically designed to suit the required location or mounting arrangement and connects by means of a NIST fitting via a flexible hose to

the distribution system. To ensure easy insertion and removal of a Medical gas probe, terminal units mounted vertically do not incorporate an anti-rotation pin.

D. Performance

Terminal Unit Performance - 400 Kpa Pressure :

Test	
Connection force	50 - 60N
Disconnection force	40 - 50N
Leakage	0.05m1 / min

Pipeline distribution pressure	Terminal unit design flow	Max P across terminal unit	Max P across terminal unit with NIST connectors and 2 meter flexible hose attached to pipe work by NIST fitting
400 Kpa	40 l/m	2.6 Kpa	2.0 Kpa
700 Kpa	250 l/m 350 l/m	30 Kpa 55 Kpa	50 Kpa 100 Kpa
Vacuum 400 mm Hg below atmospheric (760mm Hg)	40 l/m	90 mm Hg	140 mm Hg

E. Installation

Wall mounted terminal units shall be located at a height of 1300mm above finished floor level and shall not be less than 200mm from any possible obstruction. With the exception of 2 gas services of Oxygen and Medical vacuum which are spaced at 150mm between centers, Multi-gas Gem 10 installations shall be spaced at 133.5mm between centers. Wall mounted terminal units shall be mounted, when facing the units, in the following order, horizontally from left to right or vertically from top to bottom: - Oxygen, Nitrous oxide, Medical air 400 Kpa, Medical air 700 Kpa, Medical vacuum. Wall mounted terminal units shall be of exposed type.

F. Testing and Commissioning:

Although the assemblies are fully tested prior to dispatch with a manufacturer certification of compliance it is essential that full commissioning procedures are followed before the systems are brought into use.

K. Pendants

A. Flexible pendant

Flexible pendants shall be supplied and manufactured using reinforced anti-static plastic color coded flexible hose with the appropriate NIST fittings permanently attached. Pressure gas system shall incorporate a self closing shuttle valve in the first fix termination to enable hose removal without disrupting system operation. Medical gas/vacuum services shall incorporate medical gas terminal units. Each terminal unit must be shrouded by plastic cover to minimize the collection of dust or moisture. Flexible pendants shall be manufactured and installed to provide a clearance of 2 meters above finished floor level. The flexible pendant shall

incorporate medical gas and vacuum services as specified: 1 Oxygen, 1 N2O 1A4, 1A7, 2VAC.

The flexible hoses should be factory assembled and fully tested before dispatch. A manufacturer certificate of quality assurance and compliance should be submitted with each pendant.

B. Rigid pendant

Rigid pendants shall be manufactured using reinforced anti-static plastic color coded flexible hose with the appropriate NIST fittings permanently attached. Pressure gas systems shall incorporate a self closing shuttle valve in the first fix termination to enable hose removal without disrupting system operation. Rigid pendants shall be manufactured and installed to provide a clearance of 2.0 meters above finished floor level.

The mounting surface must be of sufficient strength to withstand a maximum vertical and horizontal load of 300lbs and 225lbs.

The rigid pendant shall incorporate medical gas/vacuum and electrical services as specified. Electrical installations shall conform to IEE regulations, be routed through flexible conduit and terminate in a junction box. The rigid pendant structure shall be octagonal in section and shall be maintenance free and finished in high quality 'easy clean' white enamel paint with a stainless steal fascia soft bumper strip around bottom edge of pendants to protect personnel. The pendant should be factory assembled and fully tested before dispatch. A manufacture certificate of quality assurance and compliance should be submitted with each pendant.

The rigid pendant shall incorporate medical gas and vacuum services as specified : 2 oxygen, 1 N_2O, 2A4, 1A7, 2VAC and 8 electrical sockets.

L. Testing and commissioning

A. Pressure testing

The test will be during construction and the systems will be pressure tested to a pressure of 10 bar or twice the working pressure, whichever is the greater, the system will then be isolated and the pressure recorded. The pressure reading will be then taken in 24 hours and no noticeable variation will be allowable, with the exception of pressure variation due to temperature fluctuation. If a pressure loss is detected, then the leak will be found, repaired, and another test applied. This will continue unit all leaks have been isolated.

B. Anti confusion

Tests will be carried out to ensure that all gases are connected to the correct supplies by; isolating all gases, pressuring each gas in turn, confirming that gas only comes from the pipe marked for that gas and that all other gas pipes are not pressured

TESTS AND ADJUSTMENTS (15990)

A. Scope

Execute and conduct all tests to the various systems and services shall be provided under this Contract in accordance with the requirements and instructions of this section.

B. General Requirements

The Contractor shall carry out all tests specified in this section and shall advise the Engineer by writing of the dates of commencements of all tests, partial or final.

Before tests are started, the Contractor shall submit comprehensive information describing tests shall be performed and the methods of testing shall be adopted.

Tests shall be carried out on all equipment, material and accessories supplied and installed by the Contractor.

Tests shall be conducted in compliance with the stipulations of codes of standards mentioned in this Book of Specifications as well as relevant international standard.

The contents of this section are deemed shall be complimentary to, and not in limitations to, the test clauses covered in the General Conditions of Contract of the Civil and Architectural Book of Specifications.

Labor, materials, instruments, power, water, etc..., required for testing shall be provided at no additional cost by the Contractor, unless specifically stated otherwise under the particular section of the Specifications.

Instruments shall include, but not be limited to:

a. Verniers, calipers, gauges, thermometers, etc...
b. Voltmeters, ammeters, meggers, etc...
c. Calibrated air flow meter, pump for hydrostatic pressure tests, etc...
d. Additional instruments and equipment test that may be required to run the specified tests.

Tests shall be performed in the presence of the Engineer or his representative.

Pressure tests to piping systems shall be applied before their connection to fixtures, equipment and appliances. In no case shall these latter be subject to pressures exceeding their ratings or accepted Engineering Standards of Practice.

Defective Works shall be promptly repaired or replaced and the tests shall be repeated at the Contractor's expenses until the particular system or components receives the Engineer's approval.

The Contractor shall repair and/or replace any damages or damaged materials resulting from the tests at no additional costs.

In the event of any repair or adjustment have shall be made, other than normal running adjustment, the tests shall be void and shall be repeated after the adjustments or repairs have been carried out.

When pipes, valves, ducts, equipment, etc..., are shall be covered, imbedded or insulated, their specific tests shall be carried out on them before any covering is applied. These tests shall not relieve the Contractor of any of his responsibilities, and he shall take all necessary precautions to insure the safety and protection of such tested item or systems until the termination of the Works.

The duration of tests shall be as determined by all parties having jurisdiction, but shall in no case be less than the times prescribed for each system.

Unless specifically stated otherwise in the Specifications, tests results shall not deviate by more than plus or minus five percent of the specified capacities or characteristics.

Three copies of all tests results and data shall be submitted to the Engineer after satisfactory completion of tests.

C. Equipment and Fixtures

The Contractor shall test each equipment or fixture installed under this Contract to ensure that performance and capacities conform with the Specifications.

Equipment and accessories are not shall be subjected to pressure in excess of prescribed test pressure noted in its nameplate data or manufacturer's published data.

Tests: carry out as required to test equipment for performance and proper functioning and to demonstrate, to the Engineer's satisfaction, that equipment meets design requirements.

Retest equipment if adjusted, repaired or replaced.

Data shall be measured shall be those items given on the Schedule of Equipment and including the following: entering and leaving water temperatures, entering and leaving air dry bulb and wet bulb temperature, ambient dry bulb and wet bulb temperatures, air quantities, water quantities, pressure drops on air and water sides, suction and discharge pressures, electric motor horsepower or kilowatt input from measured voltage, current and power factor, sound levels.

The following clauses illustrate tests shall be carried out on various equipment and fixtures; this enumeration shall not limit the Contractor to carry out these tests only. All equipment and fixtures whether mentioned herebelow or not shall be tested to the Engineer's complete satisfaction.

1. Air Handling Equipment

   Fans shall be tested for actual CFM and power consumption, phase current and voltage, noise and vibration, interlocks and controls.

2. Cold Generating Equipment (Condensing Units,...)

   They shall be tested for power consumption, capacities and conformity of controls with specified sequence of operation, noise and vibration.

3. Air Outlets

   Each air outlet shall be tested for actual CFM, air throw and noise.

4. Pumps

   Each pump shall be tested for actual flow, actual shut-off head, operating and discharge pressures, rpm, brake horsepower, phase current and voltage and conformity of controls with specified sequence of operation, noise and vibration.

5. Tanks and Vessels

   Unless specified otherwise, each tank and vessel shall be tested for leaks under a hydrostatic pressure equal to at least three times its specified working pressure.

   Refer to tests on pipes below for testing particulars.

D. Pipes

Unless specifically mentioned otherwise, piping systems including valves, fittings and joints, shall be tested at not less than twice the specified working pressure or ten bars whichever is higher.

Testing procedures shall conform with the following:

a. Blank-off or remove all traps, instruments, automatic valves, diaphragm valves, relief valves, etc,... or equipment which may be damaged by test pressure.

b. Open all valves.

c. Fill the system with the specified testing fluid (water, air, gas, refrigerant,...) and vent it at all high points.

d. Pressurize the system and maintain the required test pressure for a sufficient length of time to enable complete inspection of joints and connections.

e. Repair all leaks and/or defects uncovered by the tests and re-test the system.

f. Maintain test pressure for the specified length of time mentioned under each type of pipe.

g. After tests have been completed, drain the system and blow-out the testing fluid to clean it of suspended foreign materials.

h. Clean all strainers, valves and fittings of dirt, fillings and debris.

j. Do not insulate or conceal piping until tests have been completed and results approved.

Where sections of pipes are shall be covered, imbedded or buried, the required tests shall be carried out on them before they become the covering and the necessary steps taken to protect them until handing over.

1. Refrigerant Pipes

   a. Refrigerant pipes shall be tested at 15 bars for a duration of 24 hours using an inert gas.

   b. After the pressure test is successfully completed, the piping shall be dehydrated and evacuated three consecutive times, each time reaching a vacuum of 100 microns and holding it for a period of three hours and then breaking it with refrigerant gas.

   c. After charging, refrigerant pipes shall be tested by a halide leak detector.

2. Services Pipes (Except Drainage)

   Service pipes, except drainage, shall be pressure tested for 24 hours at twice the system operating pressure but not less than 10 bars without loss of pressure.

3. Drainage Piping

   a. Within the building plug piping section shall be tested and fill it at the highest point with water. No apparent loss of water shall be noted after four hours. Tests shall be carried out in floor intervals not higher than ten meters.

   b. Between manholes, pipes shall be tested by plugging the inlet pipe to the upstream manhole and the inlet pipe of the downstream manhole and filling the section with water to the top of the upstream manhole. No apparent loss of water shall be noticed after four hours.

E. Controls and Instruments

Controls and instruments shall be tested to ensure that their performance and functioning is in accordance with the requirements of their particular system and stipulations of the Specifications.

F. Electrical Installation

The Electrical Installation shall be cleaned and adjustments made before applying power. After power is applied, the following tests shall be carried out satisfactorily:

a. Continuity tests on all wires and cables.

b. Insulation tests between phases, phase to earth of each circuit as well as equipment by the use of 1000 volts megger. Reading shall be better than 0.5 meghom.

c. Earth resistance.

d. Test, panel boards and motor control centers including relays, starters, breakers, switches, etc,...

G. Balancing and Adjusting Air Distribution Systems

Regulate and balance systems to obtain required quantities of supply, return, exhaust and fresh air. Measure air quantities with velometer or anemometer.

Precautions: before operating system for balancing, ensure dampers and registers are open, filters are clean and free of air bypass, moving equipment is lubricated and all necessary inspection and maintenance work is done for proper and safe operation.

Air distribution pattern: set registers and grilles with adjustable bars at correct deflection, as determined from manufacturer's data, to produce required air distribution pattern in space without causing draughts.

Preliminary test run: perform to determine total air quantity delivered by fan at existing system static pressure. Measure air quantity at fan inlet and from each air outlet. Total air quantities measured at outlets shall be within +/-5% of air quantity measured at fan.

Total air quantity delivered is shall be adjusted by regulating fan speed with adjustable motor sheave to obtain specified air quantity. If total air quantity cannot be obtained without exceeding speed range of sheave or available motor horsepower notify the Engineer before proceeding.

Total air quantity: after this is obtained from fan, balance system for required distribution of air quantities.

Test operating devices such as automatic dampers, fire dampers, volume control dampers and splitter vanes for proper, smooth and quiet operation.

Test reports to include duct layouts showing where readings were taken, readings of air quantities as measured for supply, return, exhaust and fresh air, static pressures, details of method of balancing and instruments used.

H. System Reliability and Performance Testing

After successfully completing the above tests, each system shall undergo reliability trial tests for compliance with the specified performances stated in the Tender Documents.

Tests for air conditioning systems shall be between June 15th. and August 30th. and test for heating systems shall be between December 15th. and February 28th. Dates for tests shall be agreed with the Engineer ahead of time.

All other tests shall take place at any reasonable time subject to the Engineer's approval.

The reliability trial tests shall last for a period of seven consecutive days during which all systems and installations shall operate continuously without adjustment or repair to the Engineer's complete satisfaction.

During the reliability tests, performance tests shall be conducted on the various parts or sections of each system. Tests data shall be note and tabulated properly; results less

than ninety five percent of the specified figures shall not be accepted and shall be considered as failing to meet Contract requirements.

Should any part of the various systems or equipment fail to meet Contract requirements, it shall adjusted, repaired or replaced to the Engineer's satisfaction. Tests shall then be repeated until no faults or adjustments are required.

A taking over certificate or certificate of completion, with or without reservations, will be issued by the Engineer upon satisfactory completion of tests. The taking over certificate with reservations will be issued only if reservations are of minor importance and do not affect systems' used and satisfactory operation.

Scheduling of tests: one month before date set for commencing tests, submit for approval six copies of test procedure with tests shall be performed, method of testing, instruments shall be used, points of measurement and method of calculation. Date for commencing tests shall be subject to approval obtained at least 5 days before each trial test run.

Test results: provide six copies for approval. Include approved copies in the Instruction Manual.

Acceptance certificate shall be drawn up in 3 copies when all tests are carried out to the Engineer's satisfaction. Certificate shall be signed by the Engineer and the Contractor and one copy handed to the Contractor.

LIST OF MECHANICAL APPROVED MATERIALS

ITEM	MATERIAL
1. STEEL PIPES	DALMINE
2. ACCESSORIES FOR STEEL PIPES	CRANE, AFL
3. POLYPROPYLENE PIPES	POLYMUTAN, FUSIOTHERM
4. UPVC PIPES	OMNIPLAST, DALMINE
5. COPPER PIPES	KABEL METAL, WEDNESBURY
6. ACCESSORIES FOR UPVC PIPES	ZURN, REDI, NICOLL, SITA
7. MANHOLE COVERS AND GRATING	PAM.
8. SUPPORTS	GRINNELL, WALRAVEN, MUPRO
9. VALVES, STRAINERS	HATTERSLAY, CRANE, VAG, ISI, NIBCO, SERSEG, JENKINS, BRAUKMAN, PEGLERS
10. PRESSURE REGULATING VALVE	ZURN, O.C. KECKLEY, WATT, BELL & GOSSET
11. AUTOMATIC AIR VENTS	BRAUKMAN
12. WATER HAMMER ARRESTORS	JOSAM, ZURN
13. FLEXIBLE CONNEXIONS	MASON, ANACONDA, FLEXONICS
14. THERMAL INSULATION	ARMAFLEX, FRANCE AIR, FIBER GLASS, ST-GOBAIN
15. FIRE EXTINGUISHER	ANSUL, KIDDE,
16. PUMPS	SALMSON, GRUNDFOSS, BELL & GOSSET, RITZ, PULLEN
17. SANITARY FIXTURES	LECICO, V&B, GROHE
18. HOT WATER STORAGE TANK	THERMOR, ARISTON
19. POLYETHYLENE WATER & TANKS	N.T.G.
20. AIR CONDITIONING	CARRIER, YORK, TRANE, HITACHI, DAIKIN

ITEM	MATERIAL
21. GRILLES AND DIFFUSERS	ANEMOSTAT, TROX, TITUS, FRANCE AIR, METALLAIRE, WATERLOO
22. SOUND ATTENUATORS FLEXIBLE DUCTS	FRANCE AIR, TROX, WOODS
23. FANS	SOLYVENT-VENTEC, WOODS OF CHOCHESTER, FRANCE AIR, GREENHECK
24. MEDICAL GASES	MEDAES
25. BOILERS ,BURNERS ,RADIATORS	CHAPPEE , DE-DIETRICH
26. KITCHEN EQUIPMENT	SOLARCO, VRESSO, EQUIP HOTEL

DIVISION 16

ELECTRICAL WORKS

DIVISION 16

ELECTRICAL WORKS

INDEX

		COMMENCING ON PAGE
16010	GENERAL CONDITIONS AND REQUIREMENTS	S2-2 136/256
16116	PANELBOARDS	S2-2 138/256
16117	WIRES, CABLES AND FEEDERS	S2-2 142/256
16118	CONDUITS AND WIREWAYS	S2-2 144/256
	PROTECTION SYSTEMS	S2-2 147/256
16441	WIRING DEVICES	S2-2 153/256
16512	INTERIOR LED AND EXIT LIGHTING	S2-2 156/256
16542	EXTERIOR / SECURITY LED LIGHTING	S2-2 161/256
16610	UNINTERRUPTIBLE POWER SUPPLY SYSTEM (UPS)	S2-2 169/256
16626	VIDEO SURVEILLANCE CCTV SYSTEM	S2-2 176/256
16731	CLOCK DISTRIBUTION SYSTEM	S2-2 188/256
	DATA AND TELEPHONE SYSTEM	S2-2 189/256
	PUBLIC ADDRESS SYSTEM	S2-2 195/256
16750	NURSE CALL SYSTEM	S2-2 201/256
16771	FIRE ALARM SYSTEM	S2-2 204/256
16780	COLLECTIVE ANTENNA TV SYSTEM	S2-2 211/256
16786	BUILDING MANAGEMENT SYSTEM	S2-2 213/256
	ACCESS CONTROL SYSTEM	S2-2 232/256
	GENERATING POWER PLANT	S2-2 240/256
	LIST OF ELECTRICAL APPROVED MATERIALS	S2-2 255/256

DIVISION 16

ELECTRICAL WORKS

GENERAL CONDITIONS AND REQUIREMENTS (16010)

A. Generalities

The contractor must provide complete installations from the power supply terminals indicated on the drawings. The scope of work includes supply, installation of material and equipment as described in the specifications and/or shown on the drawings. Associated civil works including supporting structure, are also the responsibility of the Contractor.

B. General Conditions and Requirements

Work shall be carried out in accordance with the latest issue of the French regulations.

Equipment and material are to be manufactured in compliance with the relevant recommendations of the International Electro technical Commission (IEC) or approved equivalent standards.

Locations shown on the drawings indicate the approximate location of apparatus. Exact and final locations are to be coordinated with all other trades.

Work must be carried out in a neat and efficient manner in accordance with the specifications. Installations are to be complete ready for operation and fully coordinated with all other works.

Necessary items/accessories for operation of the systems are to be provided even if not mentioned in the specification/or shown on the drawings.

Wiring layout shown on drawings is to be used only as a guide. Electrical drawings must be checked against all other trades drawings.

C. General design conditions

Power will be delivered to the site by EDL at 380/220 V, 3 phases, 4 wires, 50 Hz. An earthing system should be provided.

Equipment shall be selected for continuous and trouble free service under climatic conditions of equipment location.

D. Submittals

The contractor is responsible to prepare 3 sets of shop drawings and ask for approval before any construction. These drawings are to show that the design concept is understood.

Documents relative to equipment to be supplied and installed must be submitted for approval. Therefore, no equipment may be installed before getting prior approval.

For approval, the contractor has to submit detailed manufacturer's specifications, original catalogue cuts and drawings of equipment and materials to be used.

The client reserves the right to operate operable defective equipment until its repair or replacement. Spare parts are to be supplied. These should cover the items recommended by the manufacturer for two years operation.

The contractor must guarantee the equipment/material installed for at least one year after the final hand-over. During this period, the contractor is to undertake to make good any defect without additional cost.

E. Site Tests

Acceptance tests should be carried in accordance with the regulations and standards. Equipment and labor for testing are to be provided by the contractor.

A visual inspection to check proper installation, connections and nameplate data must be carried on before testing.

Lighting and power circuits, motors, etc., must be subjected to an installation resistance test with a Megger of at least 1000 Volts operating voltage. Communications and security systems must also be subjected to a resistance test.

A continuity test to all major feeders and circuits must be done.

F. Manuals

Complete 2 sets of instruction manuals must be provided. These should cover operation, maintenance and spare parts list of all equipment and systems.

G. As-Built Drawings

Three complete sets of as-built drawings must be provided.

H. Training

The contractor must demonstrate to operating personnel the functions and operation of all equipment before handing over. The operating personnel must be trained to perform necessary adjustments to equipment, appliances and effect routine maintenance.

J. Contractor Responsibility

The Contractor shall be responsible of the work covered in this Division including the supply, transport, storage, installation, testing and delivering in good running conditions the electrical installation. The installation of all items shall be as specified and shown on drawings, catalogues.

K. Coordination of Work

The Contractor shall be responsible for coordinating the work of the Electrical installation, with that of other trades. He shall prevent interference's and conflicts and shall be the sole responsible for damages to work of other trades, already completed.

L. Guarantee

The Contractor shall guarantee his works for the duration of one year from the date of the completion certificate. He shall make good any defect, not due to ordinary wear and tear or improper use or care.

M. Payments

Payments shall be done on a monthly basis, according to the progress of the work.

PANELBOARDS (16116)

A. General Requirements

This section covers the supply and installation of main distribution board and distribution panelboards including all necessary fittings, cable termination accessories, supports and mounting frames.

All components are to comply with relevant IEC standards and mainly with IEC 439-1 for panelboards and with IEC 947 for circuit breakers and contactors.

Contractor is to submit for approval all detailed description of components supported by the original catalogue cuts. Technical data used for the selection and sizing of internal components such as busbars, earthing breakers, contactors, metering instruments, etc... are also to be submitted for approval.

In addition to the above, contractor to submit for approval prior to ordering equipment "Shop and Construction drawings" illustrating at least the details of panelboard (plan and elevation, built-in equipments, dimensions), installation details and clearances with the assigned room, single line diagram, internal wiring details, etc...

B. Main Distribution Panelboards

Contractor shall supply and install main distribution boards with all components and accessories as required and shown on the drawings.

Enclosure must be sized to fit breakers, indicated on the drawings and schedules.

Panelboards shall be minimum 600 V class, IP55, totally enclosed, factory assembled and tested, ready for installation. Construction must meet IEC requirements 529.

Cubicles must be of the interior type, floor mounted with provision in the base for fixing to a concrete plinth.

Frames are to be constructed from folded steel angles strengthened by horizontal and vertical folded channels and corner gaskets.

Frameworks are to be enclosed by electrozincated phosphated sheet stell of minimum thickness of 1.5 mm.

Boards shall be modular, each module shall have lifting eyes. When lifting eyes are bolted to the enclosure, suitable infills are to be provided so that the defined IP is not derated.

Compartment doors are to be fitted with gaskets so as to protect the interior against the ingress of dust and water when the door is closed. Compartment doors are to be rigid to prevent any distortion.

Hinges on compartment doors are to allow for the doors to be opened to greater than 90°.

The interior compartment mounting plates shall be constructed from a minimum of 2mm flat sheet steel and are to be rigidly fixed into the compartment.

Panel steelwork shall be protected against climatic conditions by degreasing the steelwork with rust inhibitor and applying two coats of primer and two top enamel finish top coats and epoxy powder baked.

The steel work paint finish shall be subjected to a corrosion resistance test at ambient temperature.

Busbar and busbar connections shall be capable of carrying continuously their rated normal current with a temperature rise taken into account in addition to withstanding the short circuit current for 1 second. Limit of temperature rise shall be based on a peak value not exceeding 45 degrees celsius.

Busbars and busbars connections shall be hard drawn, electrotinned, high conducting, hard copper running the complete length of the panel and shall be supported by synthetic bounded paper or synthetic bounded luminated wood and shall be capable of safely withstand stresses and short circuit.

Busbars bends shall be carried out in a cold state with dedicated tools in order not to devaluate the mechanical, thermal and dielectric properties of the busbars.

Minimum clearances for open indoor insulated busbars and busbar connections shall be 19mm between phase and earth and 25.4mm between phases.

Contractor must provide operation and maintenance manuals in addition to a fully detailed single line diagrams.

C. Components

C.1 Moulded Case Circuit Breakers

Circuit breakers are of the totally enclosed moulded case construction from an approved manufacturer and with front operated handle mechanism for manual operation in addition to automatic operator under overcurrent conditions.

Each pole is to have thermal bi-metallic inverse time-delay overcurrent element for overloads and instantaneous magnetic overcurrent trip element for operation under short circuit conditions.

Frame sizes are to be related to the minimum acceptable short circuit interrupting ratings. Trip current rating indicates nominal rating at which thermal overload element operates.

Moulded case circuit breakers shall be in accordance with IEC 947-2 recommendations.

A total discrimination should be provided between moulded case circuit breakers in order to make the circuit breaker immediately upstream only trips from a fault.

C.2 Miniature Circuit Breaker (MCB)

MCB to be of the thermal magnetic non-adjustable type with a minimum short circuit breaking capacity of 5KA. MCB are to operate under overload and short circuit conditions and made from high quality moulded insulating material.

Auxiliaries are to be provided as required by the design.

A total discrimination should be provided between moulded case circuit breakers and miniature circuit breakers.

C.3 Automatic Transfer Switch (ATS)

ATS to comprise 2 contactors and necessary controls for automatic transfer of power supply from normal source (EDL) to emergency source (generator) such as voltage sensing control relay, time delay relays, auxiliary switches, mechanical interlock, indicating lamps, etc... as necessary for the required operation of the system.

Contactors are to comply with IEC 947 and be 3 phase, 4 pole magnetic type (AC3 duty).

Normally open and close contacts are to be provided on each contractor as necessary.

Manual command shall be available.

C.4 Metering Instruments

Instruments are to be housed in enamelled square metal cases for flush installation. Accuracy of instruments is to be within 2%.

Voltmeters are to be of the moving iron type with zero adjuster, 90 degree angle, range 1.25 times nominal system voltage. (size 76 cm x 76 cm).

Voltmeter selector switch to be of the 7 position rotary type.

Ammeters are to be also of the moving iron type with centre zero adjuster.

90 degree angle and 2 times nominal system amperage. (size 76cm x 76cm).

Current transformers are to be of the indoor dry type with a rated secondary current of 5A.

C.5 Miscellaneous

Wiring to be neatly arranged on terminal blocks with suitable numbering. Control wires are to be copper, PVC insulated, 600V grade.

Anti-condensation heaters with disconnect switches and pilot lamps are to be provided in the switchboard controlled by a thermostat.

Power and control diagrams are to be provided and suitably located within the cubicles.

D. Surface Mounted Lighting and Power Panelboard

Panelboard cabinet shall be of the general purpose type made from hot galvanized sheet steel (15 mm) IP42 or IP55 depending on its location. Joints are to be welded and reinforced where necessary. Gutter spaces are to be at least 100 mm on all sides.

The front is to be of the cold rolled sheet steel of not less than 2.5 mm. Doors shall be provided with concealed hinges and flush lock. A coat of zinc chromate primer and one coat grey enamel finish are to be applied. Directories are to be provided on doors and typed to identify panelboards and indicate clearly circuit number and description of associated branch circuit.

Interior of panelboard consists of branch circuit breakers mounted on buses or on rails. Buses must be 98% pure electrolytic copper based on total temperature rise of 30 deg. C over ambient of 50 deg. C. Aluminum is not to be used for interior panelboard parts.

Buses are to be supported rigidly and mounted on moulded insulators. These should carry the maximum short-circuit duty of main protective device, which is at least the maximum short circuit at point of application, without showing signs of deterioration.

Screws and bolts used for making copper connections are to have lock washers.

Panelboards are to have ground earthing connector or bar welded to cabinet.

E. Panelboards supplied by specialist contactors

The panelboards listed hereafter will be supplied by mechanical or other specialist contactors.

Panelboards will be surface mounted, made form sheet steel (10/10 minimum), IP55. The breaking capacity for the breakers of these panelboards superior or equal 10KA.

F. Installation and tests

Main switchboards are to be installed on concrete bases, levelled. Concrete foundations are to be constructed in accordance with equipment manufacturer drawings. Any painted surface damaged during handling and installation is to be rectified before commissioning.

Main switchboard is to be tested on site for its completeness, component ratings, types, sizes and connections. Main and control circuits are to be checked for insulation. All tests required by the standards are to be carried on to the satisfaction of the Engineer.

G. Submittals

The following documents (but not limited to) are to be provided :

Manufacturer's catalogue cuts (for panelboards, circuit breakers characteristics, dimensions, etc.)

Shop drawings showing exact composition of each panelboard (busbar rating, frame and trip ratings of all circuit breakers, etc.) in addition to the installation details.

WIRES, CABLES AND FEEDERS (16117)

A. General Requirements

Unless otherwise indicated, wires, cables and feeders are to have copper conductors and manufactured to IEC502. Cable and wire conductors are to be stranded for sections 4mm² and above.

Current carrying capacities of conductors have been determined in accordance with the regulations for the specified type of installation and expected conditions of installation.

Installation of each conductor is to be color coded. Contractor has to maintain coding throughout the installation.

Branch circuit work originating from lighting panelboards is to be arranged as shown on the drawings. Loads on phases of panelboard feeder are to be balanced.

Final circuit wiring is to be run inside conduits. DC wiring is to be run in separate conduits from AC wiring.

Feeders to panelboards and isolating switches are to be either single conductor wires pulled inside heavy gauge rigid PVC conduits or multi-core cables run on cable trays under ceiling or cable ladders in shafts or in duct bank in ground. Cables buried directly in the ground are to be armoured.

Low current systems cables are to run inside heavy gauge rigid PVC conduits.

B. Technical Specifications

Single conductor wires and cables for wiring in conduits are to have high conductivity, electrolytic annealed copper conductors and insulated with PVC.

PVC insulated cables are to have high conductivity, electrolytic annealed copper conductors insulated with PVC flame retardant suitable for conductor temperature exceeding 65 deg.C, bedded with suitable filler and sheathed with PVC.

Bare grounding cable is to be single conductor, stranded for sections above 4 mm² , bare copper and suitable for use as ground conductor.

Two pair telephone cables for wiring to each telephone outlet are to be PVC insulated and PVC sheathed. Additional ground wire is to be provided in each cable.

Control cables are of the multicore type, PVC insulated and sheathed rated 0.6/1KV. Insulated conductors are numbered. Diameter of conductors is to be 1.5mm².

Fire resistant control cables are to be 0,6/1KV fire resistant to IEC 331, halogen free.

C. Installation of cables

Cables are to be installed in PVC rigid conduit or duct outdoors.

Fire resistant conductor wires are to installed in steel conduits.

Bunching of wires in conduits is not to exceed filling factors permitted by the regulations.

Cables terminating in outlet boxes are to be left with at least 250 mm extra length for terminations.

Single cables are to be fixed directly to walls or ceilings by metallic clips. Where three or more cables are run in parallel, they are to be fixed on galvanized steel perforated trays.

D. Submittals

The following data (but not limited to) are to be provided :

- Manufacturer's catalogue cuts (standards, construction, current carrying capacities, derating factors, etc.).
- Shop drawings showing exact routing of feeders, sub-feeders, etc.; details of supports; number and size of conductors in conduits; etc.

CONDUITS AND WIREWAYS (16118)

A. General Requirements

Unless otherwise indicated, all lighting and power circuits, communications and low current systems wiring are to be drawn inside conduits or wireways up to the various electric power consuming equipment.

Separate conduits and wireways are to be used for normal lighting and power circuits, communication and other low current systems wiring.

Junction and pull boxes of ample capacity are to be provided as required. Boxes are to remain permanently accessible.

Sizes of conduits and wireways not shown on the drawings are to be selected in accordance with the regulations and in relation to the number and size of conductors as shown in the table below:

Number of Conductors Relating To
Exterior Diameters Of Conduits

A	B			C			D		
	20	25	32	20	25	32	20	25	32
1.5	7	7	7	7	7	7	6	7	7
2.5	7	7	7	6	7	7	4	7	7
4	5	7	7	4	7	7	3	6	7
6	4	7	7	3	6	7	---	4	7
10	--	4	7	---	3	6	---	---	4

A:Section of Conductors (mm^2)
B: Straight Run
C: Run With One Bend
D: Run With Two Bends

Conduits and wire ways are to be designed, constructed and installed to provide safe and reliable installation protection.

Minimum size of conduit for Power Installations is to be 20mm (external diameter), unless otherwise indicated.

Minimum size of conduit for Low Current Installations is to be 25mm (external diameter), unless otherwise indicated.

Metallic cable trays are to be used for main power feeders.

Steel conduits are to be used for alarm and voice control circuits.

Rigid heavy gauge UPVC flame retardant conduits are to be used for all power, lighting and low current surface mounted electrical installations indoor and in ground electrical installations outdoor.

Flexible conduit of same material as corresponding conduit is to be used for connection to motors and to fixtures installed in false ceilings.

Cable and conduit fixing devices are to be metallic.

B. Rigid Heavy Gauge PVC Conduit

Material is to be of rigid unplasticized PVC with high impact and high temperature resistance, flame retardant.

Fittings are to be generally unbreakable, non-inflammable, self extinguishing plastic.

Conduits, boxes and accessories are to be assembled by glueing using appropriated connectors.

C. Flexible PVC conduit

Material to be ribbed on circumference, flame retardant PVC, high impact resistance, high temperature.

D. Steel conduits and fittings

Where the installation of steel conduits is specified they shall be heavy gauge, welded and galvanised and threaded at both ends to BS 4568 Part 1 and BS31 class B.

All conduit fittings shall be of similar materials and compatible to the particular conduit being used.

E. Cable Trays

Cable trays are to be installed as a complete system with all relevant accessories.

Material is to be from hot dip galvanized heavy gauge perforated sheet steel (thickness greater or equal to 1.5 mm) with corrosion resistant coating. Size of tray is to be determined by number and sizes of cables in accordance with the regulations.

Additional protection of fire-proof barriers should be provided where cable trays pass through walls and partitions. Cable trays are to be earthed at maximum spacing of 30m.

F. Workmanship

Conduits are not to cross pipe shafts, vents or openings.

Conduits must be installed at least 100 mm clear of and above pipes of other non-electrical services. An expansion fitting is to be provided in each conduit services run crossing an expansion joint in the structure.

Conduits are to be properly capped until wiring conductors are drawn in.

PVC rigid conduit runs are not contain more than the equivalent of two quarter bends.

Flexible conduits are to permit bending of feeder cables without damaging the conductor or the insulation.

Spacing of clamps or clips for supporting PVC conduits is not to be greater than :

Conduit size (mm)	*Maximum spacing of supports (m)*
20	0.60
25 - 50	0.75
63 - 75	0.90

Junction boxes near ceilings are to be installed to act as pull boxes.

Sleeves for cables must be filled with a fire retardant compound to prevent fire spread from one compartment to another.

G. Submittals

The following data (but not limited to) are to be provided :

- Manufacturer's catalogue cuts
- Shop drawings showing the exact routing of conduits, exact location of flexible conduits, etc...

PROTECTION SYSTEMS

A. Earthing Systems

A.1 Scope of work

This section includes complete installations to earth every source of energy and to provide protective earthing and equipotential bonding, based on the TN-S system arrangement, including:

- Main earthing terminals or bars
- Exposed conductive parts of electrical equipment
- Extraneous conductive parts
- Standby generator neutral earthing. (when available)

A.2 General requirements

Earthing system is a ring type earth electrode which consist of earthing conductors of cross-sectional area as indicated on drawings, in a closed loop, buried in exterior wall foundations underneath the water-proofing, or alternatively at 0.6 m around the perimeter of the building foundations, to which the earthing conductors are to be connected. The both ends of the loop will be connected to the earth bar in electrical room.

If the resistance of the earthing system described above does not go under 5 ohms (or otherwise as required by public authorities), additional earth rods connecting with the earth ring are to be provided.

The contractor shall install a sufficient number of rods to achieve this resistance value.

Earthing rods shall consist of a steel core covered with a copper coat.

The heads of the earthing rods shall be buried 50 cm deep in the ground. A concrete manhole having a 50 cm side shall be prepared for each earth terminal in order to facilitate maintenance operations and later reinforcement works utilizing additional elements if required to increase the earthing installation. The manhole should have a cover on which is indicated the presence of electrode in English and Arabic.

The manhole shall have a cast iron or concrete cover allowing permanent access.

The head of each earthing terminal shall be fitted with a sectioning bar allowing the isolation of this earthing element from the installation and, hence, the measurement of the earth resistance.

The earth electrode must be terminated on a main earthing bar in electrical room to which all earthing conductors, protective conductors and bonding conductors are to be connected. Two insulated main earthing conductors are to be provided, one at each end of the bar, connected via testing joints to the earth electrode. Conductor is to be sized to carry maximum earth fault current of system at point of application with final conductor temperature not exceeding 160°C for at least 5 seconds.

The connection of earthing cables to the earthing system shall be carried out by means of testing joints ensuring very good contact in an accessible position, on each main earthing conductor, between earthing terminal or bar and earth electrode.

A.3 Earthing conductors

The sections of earthing conductors of the various terminal circuits or power supply circuits of a panel shall be the same as those of the neutral conductor of the corresponding circuit, in such a way that they are not less than 2.5 mm^2. When the section-earthing conductors is different than those of the neutral conductor, it will be mentioned on the drawings.

Connections shall be carried out by permanent weld or by screw clamping.
Connections between the earthing network and equipment subject to movement shall be carried out by means of copper braids having the same sections as earthing conductors.

All insulated earthing conductors shall be yellow-green (external color). This color shall not be used for any other part of the installation.

A.4 Execution

All metallic equipment enclosures, lighting fixtures, earthing pins of sockets, all non-current carrying metal parts of the electrical systems and any other equipment or system components shall be grounded in an approved manner.

All earth connections shall terminate finally at the main switchboard earth bus and extend from there to earth electrodes.

The earth conductor shall be installed in the same conduit with the phase and neutral conductors.

A.5 Connections

Connections between earth bars and equipment frames and stranded copper cables shall be made with appropriate compression lugs, bolts, nuts and lock washers. Contact surfaces shall be thoroughly cleaned and tinned.
Lugs, bolts, nuts, washers, screws, clamps and other items which come into direct contact with copper earth bars, tapes, cables, etc., shall be non-ferrous and manufactured from brass, bronze or other suitable conducting material which will not cause electrolytic corrosion. Connection between copper and galvanized structures shall additionally be tined.

The earth bus in the main switchboard shall be connected to the panel room earth bus. The panel room earth bus shall be connected to the earthing points.

The connection between earth conductors and earth rods shall be made by means of high strength corrosion resistant copper alloy connector clamps.

A.6 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 °C, but not less than 30 mm^2 per 100 kVA of generator rating, with a minimum of 50 mm^2.

Generator earthing terminal is to be connected to main earthing bar by bare copper conductor of cross section not less than 20 mm^2 per 100 kVA of generator size, with a minimum of 35 mm^2.

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.

Extraneous 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.

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 35 mm^2 bare copper conductor (minimum size) or as required to carry maximum earth fault current for 1 second with final conductor temperature not exceeding 200 °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.

A.7 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.

Operation of residual current protective devices is to be checked.

For 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.