PART IV

STANDARD TECHNICAL SPECIFICATIONS
HVAC

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STANDARD TECHNICAL SPECIFICATIONS

for

AIR CONDITIONING AND VENTILATION INSTALLATIONS

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4.1. GENERAL

4.1.1. The Standard Technical Specifications are to be read in conjunction with the Detailed Technical Specifications as the latter are intended to amplify the former; only those portions of the Standard Technical Specification which apply to the actual project involved shall be pertinent.

4.1.2. Where Detailed Technical Specifications are at variance with Standard Technical Specifications the former shall prevail as its contents relate directly to the specific project.

4.1.3. Where reference is made to the sub-contractor, this shall be the contractor or sub-contractor appointed in terms of this contract or sub-contract as the case may be. All other specialist contractors or principle contractors associated on the project are defined specifically.

4.1.4. It is in the interests of the Sub-contractor to notify the Engineer when the installation reached various stages of completion in order that the Engineer may inspect the installation and point out discrepancies. These inspections shall be considered informal and under no circumstances shall they, in part or in whole, invalidate the requirements of the documents. Any costs incurred in correcting discrepancies shall be for the Sub-contractor's account.

4.2 CODES OF PRACTICE, LAWS AND STANDARDS

4.2.1 All workmanship and materials used in the execution of the works shall be of the highest class and, where not fully covered by the Specification, shall be carried out in conformity with best modern practice, as determined by the Engineer.

4.2.2 The entire installation shall comply fully with all relevant requirements of Governmental and Local Authorities whose jurisdiction embraces the location of the Site of the Works and the equipment provided for these installations which shall comply in every respect with:

a) National Building Regulations and Building Standard Act (Act 103 of 1977) as amended

b) Occupational Health and Safety Act (Act 85 of 1993) as amended

c) The relevant and applicable specifications and standards of the South African National Standards (SANS).

excepting only where exemption from any such regulations has first been obtained in writing from the said Authorities, provided that the prior approval of the Engineer has been obtained for the application for any exemption.

4.2.3 All electrical wiring shall comply fully with the latest edition of the Standard Regulations for the Wiring of Premises SANS 10142 and the additional requirements of any local authority that has jurisdiction over the Site of Works, as well as being in accordance with the best modern practice.

4.2.4 Wherever relevant, this Specification shall be understood to be amplified to embrace Codes of Practice and Standards promulgated by recognised authorities in the field of Air Conditioning, Refrigeration, Piping, Ventilation, Electrical Technology and all other branches of engineering science applicable to this project.

4.2.5 Standards referred to in this specification are the latest edition, including all amendments, published three calendar months or longer before the closing date of tender

4.2.6 It shall be assumed that the Subcontractor is conversant with the abovementioned requirements. Should any requirement, bylaw, or regulation, which contradicts the requirements of this document, apply or become applicable during the erection of the installation, such requirement, bylaw, or regulation shall overrule this document and the Subcontractor shall immediately inform the Engineer of such a contradiction. Under no circumstances shall the Subcontractor carry out any variations to the installation in terms of such contradictions without obtaining the written permission to do so from the Engineer.

4.2.7 It shall be the responsibility of the Subcontractor to make the necessary arrangements at his own expense with the local supply authority and to supply the labour, equipment and means to inspect, test, commission and to hand over the installation.

4.2.8 The Subcontractor shall supply and install all Notices and Warning signs that are required by the appropriate laws, regulations and/or by this document. . In addition a conformity plaque must be attached to each machine, with the following information written in English:

- Name and address of the Contractor
- Type of material
- Serial number in the type
- Date of manufacture
- Indication of conformity to the legislation of the country (*ce marking)*

4.2.9 The installation must not produce any risks, even potentially, with regard to the safety of the people, the goods and the environment, and in particular:

- Mechanical risks related to mobile moving elements
- Risk of fire and explosion
- Risk of burns related to the use of steam, refrigerant and hot water
- Risk of overpressure related to the use of steam and refrigerant
- Risk of overflow
- Electrical / electrostatic / lightning risks
- Risks of falling of persons or objects
- Risks of pollution
- Risks related to vibrations
- Risks related to noise
- Risks related to hazardous materials used
- Risk related to any of the surfaces finish (cuts, …) on all areas of implementation.
- The use of hazardous consumable materials must be kept to a minimum.

4.2.10 When so requested by the Engineer, provide evidence in the form of certificates, test reports or other written proof that material or components comply with the standards laid down in this specification.

4.2.11 Products that are specified as mark-bearing must bear the mark of the relevant standards body

4.3 CHILLED WATER GENERATORS

4.3.1 Chilled Water Generators shall be of the package type with rated capacity at site conditions at least as specified. The units shall be a standard catalogued item of the manufacturer with the performance tested

in accordance with a recognised authority. Full details of the equipment offered shall be submitted with the Tender.

4.3.2 Chillers shall be provided with a least two completely separate refrigeration circuits which can operate independently of each other.

4.3.3 Refrigerant circuits shall each be provided with a hot gas muffler, combination moisture indicator and sight glass, refrigerant filter drier, liquid line solenoid valve, thermal expansion valve and charging valve. The suction lines shall be insulated with close fitting cellular insulation.

4.3.4 Compressors shall be of the semi-hermetic type and shall have capacity control, self reversing positive displacement oil pump, serviceable oil filters, oil level sight glass and crankcase heater. The compressors shall be fully accessible and completely rebuildable locally.

4.3.5 Compressors shall be driven by a built-in three phase motors. Motors shall be cooled by suction gas passing around the motor windings and shall be thermally protected by embedded thermostats in the motor windings.

4.3.6 Condensers shall be of the shell and tube design and two separate refrigerant circuits. Water heads shall be removable to permit cleaning and replacing of tubes. Water connections shall be flanged. Condensers shall be constructed to provide positive sub-cooling of the liquid refrigerant and shall be complete with safety relief valves, purge cocks and liquid line shut off valves. The condenser capacities shall be sufficient to hold the full system refrigerant charge for pump down.

4.3.7 Water coolers (evaporators) shall be of the shell and tube type construction with removable heads and shall contain two direct expansion refrigerant circuits. Tubes shall be integrally finned seamless copper rolled into ground tube sheets. Shells shall be suitably insulated and vapour sealed.

4.3.8 Machines shall be fully factory wired, piped and charged. Control panels shall include all operating and safety controls as well as terminal strips for external power and interlocking connections. Panels shall incorporate suction and discharge pressure gauges, an oil pressure gauge, suction and discharge switches, oil pressure switch, low chilled water temperature cut-out and temperature controller controlling compressors and unloader sequential operation. Refrigerant connections to devices on the panels shall be flexible enough to prevent transmission of vibration and shall have shut-off valves.

4.3.9 Capacity control systems shall modulate compressor capacities automatically by means of built in chilled water temperature actuated controls. The compressors shall start by a sequence programmed start.

4.3.10 Reciprocating compressors shall be provided with stepped capacity control by cylinder unloading with at least four steps per compressor as well as hot gas bypass control.

4.3.11 Screw type compressors shall be provided with fully modulating control.

4.4 PACKAGED AIR CONDITIONING UNITS - WATER COOLED

4.4.1 Water cooled packaged air conditioning units shall consist of the following components all housed within, or forming part of, their steel cabinets:

Refrigeration compressor(s)
Water-cooled condenser(s)
Refrigeration pipework and controls
Refrigerant gas charge
Direct expansion cooling coil
Centrifugal supply air fans
Motor and vee-belt drive to fans
Cleanable air filters
Electrical switchpanel
Internal electrical wiring.

4.4.2 Casings shall be constructed of not less than 1,2mm thick mild steel panels suitably braced and framed so as to prevent drumming, whilst at the same time being arranged in easily removable panels to facilitate access to any portion of the internal components. Casing panels shall be attached to a sub-frame of welded mild steel sections, which framework shall also serve the purpose of holding all internal equipment in position. The casing panels shall be internally insulated with `Fibreglass' or equivalent non-combustible material, such insulation being adequately secured to the internal surface of the cabinet with a non-combustible adhesive, whilst exposed surfaces of the insulating material shall be coated or covered with a suitable bonding agent to disallow shedding of the material into the packaged unit. The casing and framework shall be thoroughly degreased and then painted with a suitable rust proofing primer prior to the application of two finishing coats of good quality enamel or lacquer in the standard colour of the manufacturer. Openings for condenser water lines, condensate drain lines and power supply lines, shall be provided on one side of the cabinet. The openings shall be provided with rubber grommets.

4.4.3 Compressors shall be of the serviceable hermetic type equipment with suitable type vibration isolators and crank case heater. Compressors shall be located in a sound attenuating compartment located in the unit cabinet. The compressor shall be protected against low oil pressure and excessive winding temperature.

4.4.4 Water cooled condensers of the tube in tube, shell and tube or shell and coil type shall be provided on each refrigerant circuit. The condenser shall incorporate a pressure relief device to comply with Government regulations. All tubing within the condensers shall be copper. Unless otherwise specified, the condenser shall be selected for a fowling factor of not less than 0,000176 m^2C/w. Threaded pipe connections shall be provided for water supply and return line.

4.4.5 Refrigeration pipework shall be carried out in seamless refrigeration quality copper tubing, suitable provision being made that the piping is not subjected to any stresses by vibration from the compressor(s). Refrigerant circuits shall incorporate replaceable type filter-dryers, sight glasses and thermostatic expansion valves and shall be factory charged with Refrigerant 22.

4.4.6 Automatic controls within the unit shall include a dual pressure refrigerant switch with manual reset on the high pressure side. Units which do not incorporate pump-down control shall incorporate timing devices to delay starting of compressors in such a manner that refrigerant pressures may first balance between stopping and starting of same.

4.4.7 Supply fans shall be of double inlet forward-curved centrifugal type with their impellers running in sealed, permanently lubricated, ball-bearing plumber blocks located in the suction eye on each side of each fan. Fan impellers shall be statically and dynamically balanced and run well below critical speed. Fan assemblies shall be so mounted within the packaged conditioner that they do not transmit any vibration. Where units having more than one fan are offered, these shall all be driven by a common motor.

4.4.8 Fan motors shall be three-phase squirrel cage type and run at not exceeding four-pole synchronous speed. The motor shall drive the fans via vee belt drive(s), each drive having not less than TWO vee belts.

4.4.9 Direct expansion cooling coils shall comprise of aluminium plate fins mechanically bonded to seamless copper tubing. The coils shall be encased in heavy gauge galvanised steel casing and fitted with a 1,4mm thick rust proofed steel condensate pan so sized and located as to prevent entrainment of condensed moisture into the air stream whilst also ensuring positive drainage of condensate to the drain connection point of adequate size.

4.4.10 Air Filters shall be equal to WASHPLEAT high performance washable pleated panel type housed in adequate holding frames fitted with gaskets to ensure a positive airtight seal around them. Should throw-away filters be the standard of the manufacturer of the packaged conditioner, they shall be discarded, and the foregoing specified type provided in their place.

4.4.11 Electrical Switch panels shall be incorporated to house all switchgear required to operate the various components within the unit. The switch-panel shall comply with best modern practice and incorporate all

necessary protection against overload or short-circuit, being fitted also with a main incoming isolator of sufficient capacity. The electrical equipment shall be fully interlocked so that the compressor cannot operate unless the remote condenser water pump is first operational and the supply air fans are running.

4.4.12 Compressor motors up to, but not exceeding 15 kW each may be started direct-on-line on application to the local authorities. Tenderers shall therefore base their pricing on the assumption that the local authority will grant an application to start compressor motors up to 15 KW each direct-on-line.

4.4.13 Compressor motors above 15 kW will have to be part-winding started and fan motors above 3,7 kW will have to be star-delta started.

4.4.14 Should the standard electrical motor starting arrangements provided by the manufacturer of the packaged air conditioning units not comply with the foregoing, the Contractor will be required to make the necessary modifications to the units to meet these requirements.

4.4.15 Internal electrical wiring shall comply fully with wiring regulations, as relevant, and be adequately secured such that it does not hang loose or exposed where it could be damaged. Adequate earthing shall be allowed.

4.5 PACKAGED AIR CONDITIONING UNITS - AIR COOLED

4.5.1 Air Cooled packaged air conditioning units shall be suitable in all respects for the unprotected outdoor location.

4.5.2 Unit(s) shall consist of the following components all housed within, or forming part of, its steel cabinet:

Refrigeration Compressor(s)

Air-cooled condenser coil(s)

Condenser fans and motors

Refrigeration pipework and controls

Refrigerant gas charge

Direct expansion cooling coil(s)

Centrifugal supply air fans

Motor and vee-belt drive to fans

Electrical heater elements

Cleanable air filters

Electrical switchpanel

Internal electrical wiring

4.5.3 Casings shall be constructed of not less than 1,2mm thick mild steel panels suitably braced and framed so as to prevent drumming whilst at the same time being arranged in easily removable panels to facilitate access to any portion of the internal components. Casing panels shall be attached to a sub-frame of welded mild steel sections, which framework shall also serve the purpose of holding all internal equipment in position. The casing panels shall, unless otherwise specified, be double skin internally insulated with `Fibreglass' or equivalent non-combustible material, such insulation being adequately secured to the internal surfaces of the cabinet with a non-combustible adhesive. Exposed surfaces of the insulating material shall be coated or covered with a suitable bonding agent to disallow shedding of the material into

the packaged unit. All mild steel casing panels and framework shall be thoroughly degreased and then painted with a suitable rust proofing primer prior to the application of two finishing coats of good quality enamel or lacquer in the standard colour of the manufacturer.

4.5.4 Units shall contain either a single refrigeration compressor or may be fitted with multiple compressors. Refrigeration compressors shall be of the hermetic or the accessible hermetic type direct driven by integral suction gas cooled squirrel cage motors at the rotational speed of not exceeding 1500 R.P.M. Compressors shall be mounted on helical spring type vibration mountings. Hermetic motors shall be protected against excessive winding temperatures. The compressors shall be complete with positive displacement reversible force-feed lubrication systems, have low oil pressure protection devices and contain crankcase oil heaters to ensure boil-off of dissolved refrigerant from lubricating oil at such times as when the compressors are stationary.

4.5.5 Units incorporating only one compressor shall be provided with at least two stages of capacity modulation other than full load and shall also be arranged to start in an unloaded position.

4.5.6 Condenser coil(s) shall, unless otherwise specified, consist of copper tubes fitted with mechanically bonded aluminium plate fins, all housed in a robust galvanised steel frame and protected with a suitable galvanised wire mesh screen to prevent mechanical damage to the coil due to hail.

4.5.7 Condenser fans shall be of the slow-running propeller type direct or belt driven by squirrel cage electric motors. The unit shall be provided with a minimum of four or more propeller fans which shall be arranged for vertical discharge through suitably weather-proofed protective wire guards which guard shall provide adequate hail protection. The fan and motor bearings shall be of the permanently lubricated sealed type and the motors shall be resiliently mounted so as not to transmit vibrations to the unit casing.

4.5.8 Condenser air intake and discharge arrangements shall be such that no short-circuited discharge air can be drawn back into the air intake.

4.5.9 Refrigeration pipework shall be carried out in seamless refrigeration quality copper tubing, suitable provision being made that the piping is not subjected to any stresses by vibration from the compressor(s). The refrigeration system shall be split into at least two stages on the liquid side for adequate capacity control. Refrigerant circuits shall incorporate replaceable type filter-dryers, sight glasses, thermostatic expansion valves as well as vapour-proof insulation on the suction lines. The unit shall be factory-charged with refrigerant.

4.5.10 Automatic controls within the unit shall include a dual pressure refrigerant switch with manual reset on the high pressure side and an oil pressure switch with manual reset.

4.5.11 Provision shall be made for pressure relief of the high side refrigerant piping in compliance with government regulations. Provision shall also be made for cycling the condenser fans so that the unit may be capable for operating at full load, down to an ambient temperature of 5ºC db.

4.5.12 Direct expansion cooling coils shall consist of at least two separate refrigerant circuits and shall comprise copper tubes with mechanically bonded aluminium fins. The coil shall be encased in a heavy gauge galvanised shell casing and fitted with a 1,4mm thick rust proofed steel condensate pan so sized and located as to prevent entrainment into the air stream of condensed moisture, whilst also ensuring positive drainage of condensate to a drain connection point of adequate size.

4.5.13 An anti freeze thermostat shall be provided to sense the return air temperature and arranged to reduce the cooling steps available on the compressor and prevent icing of the evaporator coil when the return air temperature is low.

4.5.14 Supply fans shall be of double inlet forward-curved centrifugal type with their impellers running in sealed, permanently lubricated, ball-bearing plumber blocks located in the suction eye on each side of each fan. Fan impellers shall be statically and dynamically balanced and run well below critical speed. Fan assemblies shall be so mounted within the packaged conditioner that they do not transmit any vibration. Where units having more than one fan are offered, these shall all be driven by a common motor.

4.5.15 Fan motors shall be three phase squirrel cage type rated not less than 25% above the power input absorbed by the fans and run at not exceeding four-pole synchronous speed. The motor shall drive the fans via a vee belt drive having not less than two vee belts.

4.5.16 Heater elements shall be of the factory-bent Incoloy type, rated for still air and fitted into the casing in such a manner as to ensure full air flow over each element. The heater elements shall be fitted into a withdrawable fabricated galvanised sheet metal channel frame. The side on which the terminals are located shall be fitted with a terminal box of sufficient size to contain all necessary electrical wiring, the terminal box being fitted with a removable weatherproofed cover so fastened that no screw shall project into the actual terminal box. The electrical wiring within the terminal box shall be effected in Asbestos-Insulated copper wiring capable of withstanding the temperatures to be encountered without breakdown of the insulation.

4.5.17 Air Filters shall be equal to WASHPLEAT high performance washable pleated panel type housed in adequate holding frames fitted with gaskets to ensure a positive airtight seal around them. Should throw-away filters be the standard of the manufacturer of the packaged conditioner, they shall be discarded and the foregoing specified type provided in their place.

4.5.18 A weatherproof electrical switchpanel shall be incorporated to form part of the unit and shall house all switchgear required to operate the various components within the unit. The switchpanel shall comply with best modern practice and incorporate all necessary protection against overload or short-circuit, being fitted also with a main incoming isolator of sufficient capacity. The electrical equipment shall be fully interlocked so that cooling and heating cannot operate simultaneously and so that the compressor cannot operate unless the condenser fans are first operational and the supply air fans are running.

4.5.19 Wiring within the panel and the unit shall comply with wiring regulations as relevant and shall be neatly grouped to horizontal and vertical runs and bound with P.V.C. tape. All wiring shall also be colour-coded in the colours red, yellow and blue for the relevant phases and black for neutral, and busbars being similarly marked. Busbars shall be copper of adequate cross-sectional area, suitably spaced and mounted on stand-off type porcelain insulators, all exposed current carrying parts, connection strips, etc., must be fully insulated in P.V.C. tape of the colours mentioned above. All outgoing leads shall be connected to a marked terminal strip.

4.5.20 Panels shall be fully labelled with black Ivorine labels having 5mm high white lettering and riveted to the cover plates previously referred to. Labels which are merely affixed with adhesive will NOT be acceptable.

4.6 REFRIGERATION CONDENSING UNITS - AIR COOLED

4.6.1 Air Cooled refrigeration condensing units shall be suitable in all respects for the unprotected outdoor location and shall comprise essentially of the following components all factory assembled onto a rigid framework constructed of mild steel sections, and housed within, or forming part of its steel or fibreglass cabinet:

Refrigeration Compressor(s)

Air-cooled condenser coil(s)

Condenser fans and motors

Refrigeration pipework and controls

Refrigerant gas charge

Electrical switchpanel

Internal electrical wiring.

4.6.2 Casings shall be constructed of not less than 1,2mm thick mild steel panels suitably braced and framed so as to prevent drumming, whilst at the same time being arranged in easily removable panels to facilitate access to any portion of the internal components. Casing panels shall be attached to a sub-frame of welded mild steel sections, which framework shall also serve the purpose of holding all internal equipment in position. All mild steel casing panels and framework shall be thoroughly degreased and then painted with a suitable rust-proofing primer prior to the application of two finishing coats of good quality enamel or lacquer in the standard colour of the manufacturer.

4.6.3 Units shall contain either a single refrigeration compressor or may be fitted with multiple compressors. Refrigeration compressors shall be of the serviceable hermetic type direct driven by integral suction gas cooled squirrel cage motors at a rotational speed of not exceeding 1500 R.P.M. Compressors shall be mounted on helical spring type vibration mountings. Hermetic motors shall be protected against excessive winging temperatures. The compressors shall be complete with positive displacement reversible force-feed lubrication systems, have low oil pressure protection devices and contain crankcase oil heaters to ensure boil-off of dissolved refrigerant from lubricating oil at such times as when the compressors are stationary.

4.6.4 Units incorporating only one compressor shall be provided with at least two stages of capacity modulation other than full load and shall also be arranged to start in an unloaded position.

4.6.5 Condenser coil(s) shall consist of copper tubes fitted with mechanically bonded aluminium plate fins, all housed in a robust galvanised steel frame and protected with a suitable galvanised wire mesh screen and hail guard.

4.6.6 Condenser fans shall be of the slow-running propeller type direct or belt driven by squirrel cage electric motors. The unit shall be provided with a minimum of four or more propeller fans which shall be arranged for vertical discharge through suitably weather-proofed protective wire guards. The fan and motor bearings shall be of the permanently lubricated sealed type and the motors shall be resiliently mounted so as not to transmit vibrations to the unit casing. The fans shall be protected against hail.

4.6.7 Refrigeration pipework shall be carried out in seamless refrigeration quality copper tubing, suitable provision being made that the piping is not subjected to any stresses by vibration from the compressor(s). The refrigeration system shall be split into at least two stages on the liquid side for adequate capacity control. Refrigerant circuits shall incorporate replaceable type filter-driers, sight glasses, thermostatic expansion valves as well as vapour-proof insulation on the suction lines.

4.6.8 The unit shall be factory-charged with a refrigerant acceptable in terms of the Montreal protocol and approved by the engineer.

4.6.9 Automatic controls within the unit shall include a dual pressure refrigerant switch with manual reset on the high pressure side and an oil pressure switch with manual rest.

4.6.10 A weatherproof electrical switchpanel shall be incorporated to form part of the unit and shall house all switchgear required to operate the various components within the unit. The switchpanel shall comply with best modern practice and incorporate all necessary protection against overload or short-circuit, being fitted also with a main incoming isolator of sufficient capacity. The electrical equipment shall be fully interlocked so that the compressor cannot operate unless the condenser fans are first operational.

4.6.11 Wiring within the panel and the unit shall comply with wiring regulations as relevant and shall be neatly grouped to horizontal and vertical runs and bound with P.V.C. tape. All wiring shall also be colour-coded in the colours red, yellow and blue for the relevant phases and black for neutral, the busbars being similarly marked. Busbars shall b copper of adequate cross-sectional area, suitably spaced and mounted on stand-off type porcelain insulators, all exposed current-carrying parts, connection strips, etc., must be fully insulated in P.V.C. tape of the colours mentioned above. All outgoing leads shall be connected to a marked terminal strip.

4.6.12 Panels shall be fully labelled with black ivorine labels having 5mm high white lettering and riveted to the cover plates previously referred to. Labels which are merely affixed with adhesive will NOT be acceptable.

4.7 ROOM AIR CONDITIONING UNITS

4.7.1 Room air conditioning units shall be self contained units consisting of unit casings, compressor, evaporator, evaporative fan, condenser, condenser fan, expansion device, refrigerant pipework and controls. The condensing unit shall either form an integral part of the unit for through the wall applications or be separate for split system applications.

4.7.2 Unit casings shall be of sheet metal construction with a baked enamel finish to give an aesthetically pleasing effect as well as ensuring corrosion resistance.

4.7.3 Evaporator fans shall be of the double inlet centrifugal type with integral motor centrally located on a common drive shaft. The motor fan assemblies shall be installed to provide an even air flow across the evaporators as well as the discharge grilles.

4.7.4 Evaporators shall be aluminium fins on copper coil construction and installed to ensure that there is effective condensate drainage for the coil without carry over.

4.7.5 Condensate trays shall be provided under the evaporator to collect condensate. The tray shall be stainless steel, polyurethane or similar non corrosive material.

4.7.6 Condensate shall be disposed of at the condensing unit by evaporating the condensate on the warm condenser coils.

4.7.7 Filters, of the washable type, shall be provided behind the return air grilles. Filters shall be easily removable. Return air grilles on console and split console units shall be positioned in the front facia to enable the units to be mounted on the floor.

4.7.8 Room temperature shall be controlled by means of a thermostat which will automatically switch the compressor or heater on and off. The temperature setting shall be adjustable within an acceptable comfort range.

4.7.9 Compressors shall be of the totally hermetic dome type to operate on 220 volt single phase power supply. Compressors shall be protected against overload.

4.7.10 Condenser coils shall be copper tubes with copper fins for all coastal applications. For inland areas aluminium fins will be accepted.

4.7.11 Condenser fans shall be either propeller or of the centrifugal type and driven by means of a two speed motor arranged to automatically control refrigerant head pressure.

4.7.12 Console units shall be provided complete with wall sleeves, weather louvres and external architraves. Wall sleeves shall be handed to the builder for building in. It is the responsibility of the Subcontractor to ensure that sleeves are installed correctly and the builder shall be provided with detailed instructions regarding installation requirements.

4.7.13 Refrigerant piping for split air conditioning units shall be installed as specified herein. Reference shall be made to the manufacturer's specification regarding pipe sizes, refrigerant lift and pipe lengths. Precaution s shall be taken to ensure efficient oil return compressors and where required, additional oil shall be introduced into the system.

4.7.14 Units shall be suitably insulated to ensure quiet operation.

4.8 AIR HANDLING UNITS

4.8.1 Air handling units may be provided as complete proprietary packages and suitably adapted to meet the specification requirements or alternatively, complete built up air handling units may be offered.

4.8.2 Casings downstream of the coil and including coil sections shall be double skin insulated, to include top, side and bottom panels. Casings upstream of the coil shall be single skin insulated panels.

4.8.3 Panels shall be manufactured from the following materials;

4.8.3.1 Two skins of minimum 1mm thick galvanised mild steel or 3 CR 12 of 304 stainless steel or 1,5mm aluminium sheet metal sandwiching 50mm of insulating materials being foam polyurethane having a density of not less than 36 kg/m.

4.8.3.2 Galvanised, Aluminium and 3 CR 12 sheet metal surfaces shall be painted internally and externally and finished with high gloss epoxy enamel after suitable corrosion protection.

4.8.3.3 Stainless steel casings shall be finished with two coats of high gloss epoxy suitably applied.

4.8.4 Panels shall be fastened together using suitable inert fasteners. The assembled casings shall be air tight with joints between panels sealed by the application of a suitable silicone sealant during construction.

4.8.5 Casings support framework shall be 304 stainless steel sheet metal sections. Stiffening of the casings shall be provided to eliminate drumming under operating conditions.

4.8.6 Condensate trays shall be provided under the complete coil sections to catch any condensate including that due to carry over. Condensate trays shall be suitably insulated with a minimum of 15mm thick isosinurate foam faced with an additional aluminium foil vapour barrier to prevent condensation.

4.8.7 Coil sections shall have heavy duty coil tracks extending the full width of the unit to provide slip-in, slip-out coils for easy service and maintenance. Where cooling coils are stacked, they are to have intermediate drain pans with drop tubes at each end to drain condensate to the main drain pan without flooding the lower coil.

4.8.8 Cooling coils are to be ripple corrugated plate fins on staggered copper tubes. Fins shall have bevelled collars and shall be bonded to the tubes by mechanical expansion. The minimum fin spaces shall not be less than 8 fins per 25mm.

4.8.9 Design of the air handling unit shall ensure an even distribution across the coil banks without leakage between or around the coils.

4.8.10 Fans incorporated within the casings shall be of the double inlet double width centrifugal type as later specified herein, refer Clause 4.22.

4.8.11 Access doors shall be provided on the units to give access to the fan, filter and coil sections. Door openings shall be not less than 600 x 600mm. Doors shall be manufactured similar to the unit panels and door frameworks and appurtenances shall be constructed of stainless steel. The doors shall be hinged and provided with cam locks which can be operated from either side of the door.

4.9 FAN COIL UNITS

4.9.1 Units shall be of the type and arranged for the mounting or as later specified herein and shall consist of the following components all housed within, or forming part of their steel cabinets:

Chilled water fed cooling coil and controls

Electric heater battery

Centrifugal supply air fans

Motor with direct drive to fans

Cleanable air filters

Internal electrical wiring

4.9.2 Casings shall be constructed of not less than 1,0mm thick mild steel panels suitably braced or framed so as to prevent drumming, whilst at the same time being arranged in easily removable panels to facilitate access to any portion of the internal components. The casing panels shall be internally insulated with non-combustible material, such insulation being adequately secured to the internal surfaces of the cabinet with a non-combustible adhesive. The casing and framework shall be thoroughly degreased and then painted with a suitable rust proofing primer prior to the application of two finishing coats of good quality enamel in the standard colour of the manufacturer.

4.9.3 Coils shall comprise of aluminium plate fins mechanically bonded to seamless copper tubing. The coils shall be encased in heavy gauge galvanised steel casings. Units with cooling coils shall be provided with insulated condensate drip pans extended on the coil connection side so as to accommodate condensation from pipe connections and valves.

4.9.4 Fans shall be centrifugal, forward curved, double width constructed of corrosion resistant aluminium. Fan scrolls shall be of moulded reinforced plastic for maximum corrosion resistance.

4.9.5 Motors shall be wound for three speeds and of shaded pole construction with bronze sleeve type bearings with oil reservoirs.

4.9.6 Filters shall be easily accessible and shall be of the cleanable plastic foam type in a rigid frame.

4.9.7 Supply air grilles shall be multi-directional of extruded aluminium or plastic.

4.9.8 Valves and all automatic controls shall be incorporated as later specified herein.

4.10 REFRIGERATION PIPEWORK

4.10.1 Refrigeration pipework between refrigeration condensing units and direct expansion cooling coils in air handling units shall be installed in full accordance with the relevant diagrams.

4.10.2 Refrigeration piping shall be carried out in seamless, bright, clean refrigeration quality copper tubing received from its suppliers with capped or sealed ends. Soft annealed tubing shall be used on all pipe sizes below 19mm O.D. whilst hard drawn tubing shall be utilised on all larger sizes. Joints on soft copper lines shall be flared type, forged or drawn brass fittings similar or equal to 'Mueller-Brass' being used. For joints on hard drawn copper lines use sweat fittings in conjunction with a suitable flux and silver solder. All pipe cuts shall be neatly reamered and cleaned prior to making joints. When brazing any refrigeration pipework, dry nitrogen must be bled through system continuously to stop any build-up of oxidisation in the system.

4.10.3 Liquid refrigerant lines shall incorporate the following components should they not be included within the refrigeration condensing units:

Y-type full-flow strainers

Isolating valves of the diaphragm type to the filter dryers

Moisture-indicating type single part liquid sight glasses

Angle-type, backseating, capped liquid charging valves with flare charging connections fitted with flare-fitting cap nuts

Liquid line solenoid valves

Thermostatic expansion valves of the external equaliser type, at the air handling units

4.10.4 Vibration eliminators of 'ANACONDA' or equal make shall be installed in the positions indicated on the diagrams.

4.10.5 Suction lines shall be vapour-proof insulated with 38mm thick preformed 'ARMAFLEX' sections.

4.10.6 Refrigeration pipework shall be supported at not exceeding 2m centres. Pipes shall be securely clamped to points of support using suitable holderbats. Insulated piping shall have moulded cork inserts of 50mm thickness in place of normal insulation where supports occur, vapourproofing at such positions being carefully executed.

4.10.7 All refrigeration pipework passing through plantroom walls shall have moulded cork surrounds of 50mm thickness by width not less than that of the wall, vapourproofing at such positions being carefully executed.

4.10.8 The sensing bulb of the thermostatic expansion valves shall be securely fastened to the suction lines using copper strip and brass screws, then insulated.

4.10.9 Particular care shall be exercised to ensure that pipework is neatly run in straight lines, this applying the more so to soft copper tubing. Pipes shall pitch 25mm in 6m in the direction of flow to prevent oil traps. No pipes shall be left opened for any period of time.

4.10.10 Oil traps shall be provided on all risers and where necessary, dual risers shall be installed to ensure proper oil return.

4.10.11 All refrigerant pipework shall be colour coded to enable immediate identification at any part of the run at approximately 3 metre intervals.

4.11 REFRIGERANT CHARGE

4.11.1 Refrigerant piping systems shall be charged with refrigerant after evacuation and testing for leaks as outlined below, it being required that the Subcontractor guarantee the installation with respect to loss of refrigerant for the full guarantee period applicable to the Works.

4.11.2 Completed refrigerant circuits shall be tested by means of dry Nitrogen to a pressure of at least 50% above working pressure.

4.11.3 With the system under the pressure of the Nitrogen, brush all possible points of leakage with a solution of soap and water to which a few drops of Glycerine have been added. All soldered joints shall be tapped on with a hammer to break possible flux seals. Any leaks which may be found due to bubbling of the soapy water should be made good after the Nitrogen has first been released. "Patching-up" of a leaking joint is not permitted; the fitting shall be taken out, cleaned and resoldered into the pipework again.

4.11.4 Systems should next be charged with Refrigerant to a minimum pressure of 200 kPa and then be brought to a pressure of at least 50% above working pressure with dry Nitrogen. A 'Halide' or Electronic leak detector shall at this stage be used to detect any further leaks.

4.11.5 Systems found to be free of leaks should be allowed to remain under the pressure for a 24-hour period. If no pressure drop is observed after this period, due cognisance being taken of ambient air temperatures, the Nitrogen mixture may be discharged to atmosphere.

4.11.6 The system shall then be evacuated by means of a suitable vacuum pump to a vacuum of 2,5mm of Mercury, allowed to stand for 12 hours and, no pressure rise having occurred, may be charged with refrigerant via the charging valve.

4.11.7 The refrigerant charge shall be sufficient to ensure the correct evaporative and condensing temperatures to ensure efficient operation of the plant.

4.11.8 Make reference to manufacturer's instructions to ensure correct refrigerant charge dependent on length of pipe runs. When recommended pipe runs are exceeded, make reference to manufacturer's instructions regarding additional oil charge. The Subcontractor shall provide the recommended refrigerant and oil charge.

4.12 COOLING TOWERS

4.12.1 Cooling towers shall be of such a capacity as to match the heat rejection requirements of the Water Cooled refrigeration plant whilst being selected in accordance with the air entering wet bulb temperature given in Part V of the Specification.

4.12.2 Cooling towers shall be of the forced draft type, rectangular in shape and of sectional steel construction. Towers shall consist of three removable sections namely, the fan section, water spray and eliminators section, the third section forming the sump and air distribution plenum.

4.12.3 Forced draft fan sections shall consist of a double inlet forward bladed centrifugal fan fitted into rectangular steel-clad framework so as to form rectangular air entry plena on either side of the fan's suction eyes. The air entrances to the foregoing plena shall be protected with readily removable wire mesh guards. Fan shafts shall be extended beyond one side of the rectangular casing so as to be capable of accepting an outboard driving pulley. Fan bearings shall be located on either side of the rectangular casing accessible via the removable air inlet screens and be of the self-aligning sleeve type. The fan's air volume shall be readily controlled by means of a single aerofoil-bladed damper vane located in the fan discharge and arranged so as to accept readily a damper motor controller.

4.12.4 Driving motors serving the cooling tower fans shall be of the totally enclosed fan cooled squirrel cage three phase type and run at a speed of not exceeding 1500 rpm. The motors shall be mounted on a suitable adjustable base for belt tensioning, the base being located on top of the fan section previously specified. Belt drives shall be adequately rated and shall consist of not less than TWO vee belts and be fitted with a substantial drive guard.

4.12.5 Sump and air distribution sections shall be constructed of heavy gauge hot dip galvanised steel and be complete with the following built-in components:

Fan discharge evase, sloped to disallow water entering the fan and projecting well into the cooling tower.

Access panels, readily removable and watertight.

Pump suction screens, easily removable for cleaning.

Pump suction pipe connections and internal intake piping, all arranged to disallow water cavitation.

Ball-float make-up with suitable provision for mains water supply connections.

Eliminator and water distribution sections shall be of like construction to the sump and air distribution section, and shall each house:

A wet deck tower fill of efficient design constructed of non-corrodible modular metal sections coated with rustproof bitumenised paint, or formed plastic sections.

A spray tree consisting of a galvanised steel pipework header, similar branches and readily removable non-clog brass atomising spray nozzles.

Hot dip galvanised steel moisture eliminators, arranged in easily removable frame sections and of good efficiency.

All necessary supports for the foregoing items.

4.12.6 Cooling towers shall be heavily paint-coated with a high quality corrosionproof paint, which paintwork shall be made good as required once the tower has been installed.

4.12.7 Cooling towers shall be the product of an acknowledged and reputable manufacturer of the type to produce the heat rejection capacity specified in Part V of these Specification.

4.12.8 Bases shall be provided in accordance with the manufacturer's instructions. Cooling towers shall be mounted on suitable R.S.J.s which in turn shall be mounted on vibration insulators all to ensure that the tower does not distort or leak.

4.13 CLOSED CIRCUIT COOLING TOWERS

4.13.1 Unit construction shall be all hot dip galvanised steel and shall consist of a fan section, water spray and eliminator section, sump and plenum section, circulating pump and heat exchanger section.

4.13.2 Forced draught fan sections shall consist of double inlet forward curved centrifugal fans as later specified herein, refer Clause 4.22. Fan housings shall be arranged to prevent water from entering the fans. Fans shall be statically and dynamically balanced. Fan bearings shall be self aligning ball bearings, suitable for a 200 thousand hour average life. Fan shafts shall have exposed surfaces coated with a rust preventative.

4.13.3 Fan motors shall be suitable for outdoor operation and shall be mounted on an adjustable base for belt tensioning. Fans shall be driven through V-belt drives. The motor nameplate power shall exceed the brake power by a minimum of 15% and the motors shall be suitable for the starting method as later specified herein, refer Clause 4.23.

4.13.4 Belt drives shall be designed for a minimum of 25% overload with no less than two matched belts being used. Belts shall be selected and installed in accordance with BS 3790 1973.

4.13.5 Pulleys shall be of the taper lock type and shall be accurately keyed to the shafts and aligned before the system is put into operation.

4.13.6 Belt guards shall be provided and arranged to permit oiling, use of tachometers and other testing and maintenance operations with the guard in place. Guards shall have a front screen of expanded metal.

4.13.7 Heat exchanger sections shall consist of galvanised steel tube bundles enclosed in galvanised steel panels. The entire section shall be removable from the fan and water distribution system. Tube bundles shall have sloping tube to permit the free drainage of the fluid. A vent connection shall be provided at each tube bundle.

4.13.8 Eliminator and water distribution sections shall house wet deck tower spray trees and drift eliminators. Eliminators shall be constructed of extra heavy coated hot dip galvanised steel and shall be removable in easily handled sections. They shall have a minimum of three directional changes with a hooked leaving edge and shall direct leaving air away from the fans.

4.13.9 Pumps shall be of the close coupled centrifugal type with mechanical seals and completely piped to suction strainers and water distribution systems shall be provided and installed on the pan sections such that the suction is flooded at all times and that the pumps will drain freely when the sump is drained.

4.13.10 Sumps shall have sufficient capacity so that air will not be entertained in the outlets when operating and no water will overflow on shut down. Sumps shall be provided with an outlet connection, overflow, valved drain, quick fill and float controlled water make-up. Outlet connections shall be equipped with a suction strainer with mesh size sufficient to retain matter which could block the spray nozzles.

4.13.11 The entire unit shall be mounted on a separate steel base frame.

4.13.12 The unit shall be painted with a high quality corrosion-proof paint, which paintwork shall be made good after installation.

4.14 EVAPORATIVE CONDENSERS

4.14.1 Unit construction shall be all hot dip galvanised steel and shall consist of a fan section, water spray and eliminator section, sump and plenum section, circulating pump and heat exchanger section.

4.14.2 Forced draught fan sections shall consist of double inlet forward curved centrifugal fans as later specified herein, refer Clause 4.22. Fan housings shall be arranged to prevent water from entering the fans. Fans shall be statically and dynamically balanced. Fan bearings shall be self aligning ball bearings, suitable for a 200 thousand hour average life. Fan shafts shall have exposed surfaces coated with a rust preventative.

4.14.3 Fan motors shall be suitable for outdoor operation and shall be mounted on an adjustable base for belt tensioning. Fans shall be driven through V-belt drives. The motor nameplate power shall exceed the brake power of a minimum of 15% and the motors shall be suitable for the starting method as later specified herein, refer Clause 4.23.

4.14.4 Belt drives shall be designed for a minimum 25% overload with no less than two matched belts being used. Belts shall be selected and installed in accordance with BS 3790 1973.

4.14.5 Pulleys shall be of the taper lock type and shall be accurately keyed to the shafts and aligned before the system is put into operation.

4.14.6 Belt guards shall be provided and arranged to permit oiling, use of tachometers and other testing and maintenance operations with the guard in place. Guards shall have a front screen of expanded metal.

4.14.7 Heat exchanger sections shall consist of galvanised steel tube bundles enclosed in galvanised steel panels. The entire section shall be removable from the fan and water distribution system. Tube bundles shall have sloping tube to permit the free drainage of the liquid refrigerant. Tube bundles shall be tested to 2700 kPa air pressure while immersed in water.

4.14.8 Eliminator and water distribution sections shall house wet deck tower spray trees and drift eliminators. Eliminators shall be constructed of extra heavy coated hot dip galvanised steel and shall be removable in easily handled sections. They shall have a minimum of three directional changes with a hooked leaving edge and shall direct leaving air away from the fans.

4.14.9 Recirculating pumps shall be of the close coupled centrifugal type with mechanical seals and completely piped to suction strainers and water distribution systems shall be provided and installed on the pan sections such that the suction is flooded at all times and that the pumps will drain freely when the sump is drained.

4.14.10 Sumps shall have sufficient capacity so that air will not be entertained in the outlets when operating and no water will overflow on shut down. Sumps shall be provided with an outlet connection, overflow, valved drain, quick fill and float controlled water make up. Outlet connections shall be equipped with a suction strainer with mesh size sufficient to retain matter which could block the spray nozzles.

4.14.11 The entire shall be mounted on a separate steel base frame.

4.14.12 The unit shall be painted with a high quality corrosion-proof paint, which paintwork shall be made good after installation.

4.14.13 Evaporative condensers shall be of such a capacity as to match the heat rejection requirements of the refrigeration plant whilst being selected in accordance with the air entering wet bulb temperature given in the detailed Specification.

4.15 AIR COOLED CONDENSERS

4.15.1 Air cooled condensing units shall be suitable in all respects for the unprotected outdoor location and shall comprise essentially of the following components all factory assembled onto a rigid framework constructed of mild steel sections, and housed within, or forming part of, its steel or fibreglass cabinet:

Air-cooled condenser coil(s)

Condenser fans and motors

Refrigeration pipework

Refrigerant gas charge

Electrical switchpanel

Internal electrical wiring

4.15.2 Casings shall be constructed of not less than 1,2mm thick mild steel panels suitably braced and framed so as to prevent drumming, whilst at the same time being arranged in easily removable panels to facilitate access to any portion of the internal components. Casing panels shall be attached to a sub-frame of welded mild steel sections, which framework shall also serve the purpose of holding all internal equipment in position. All mild steel casing panels and framework shall be thoroughly degreased and then painted with a suitable rust proofing primer prior to the application of two finishing coats of good quality enamel or lacquer in the standard colour of the manufacturer.

4.15.3 Units shall contain either single or dual condenser coils to suit the refrigerant circuiting.

4.15.4 Condenser coil(s) shall consist of copper tubes fitted with mechanically bonded aluminium plate fins, all housed in a robust galvanised steel frame and protected with a suitable galvanised wire mesh screen and hail guard.

4.15.5 Condenser fans shall be of the slow-running propeller type direct or belt driven by squirrel cage electric motors. The unit shall be provided with a minimum of our or more propeller fans which shall be arranged for vertical discharge through suitably weatherproofed protective wire guards. The fan and motor bearings shall be of the permanently lubricated sealed type and the motors shall be resiliently mounted so as not to transmit vibrations to the unit casing. The fans shall be protected against hail.

4.15.6 Condenser air intake and discharge arrangements shall be such that no short-circuited discharged air can be drawn back into the air intake.

4.15.7 Refrigeration pipework shall be carried out in seamless refrigeration quality copper tubing, suitable provision being made that the piping is not subjected to any stresses by vibration from the compressor(s).

4.15.8 Provision shall be made for pressure relief of the high side refrigerant piping in compliance with Government regulations. Provision shall also be made for cycling the condenser fans so that the unit may be capable of operating at full load down to an ambient temperature of 0ºC db.

4.15.9 A weatherproof electrical switchpanel shall be incorporated to form part of the unit and shall house all switchgear required to operate the various components within the unit. The switchpanel shall comply with best modern practice and incorporate all necessary protection against overload or short-circuit, being fitted also with a main incoming isolator of sufficient capacity. The electrical equipment shall be fully interlocked so that the compressor cannot operate unless the condenser fans are first operational.

4.15.10 Wiring within the panel and the unit shall comply with wiring regulations as relevant and shall be neatly grouped to horizontal and vertical runs and bound with P.V.C. tape. All wiring shall also be colour-coded in the colours red, yellow and blue for the relevant phases and black for neutral, the busbars being similarly marked. Busbars shall be copper of adequate cross-sectional area, suitably spaced and mounted on stand-off type porcelain insulators, all exposed current-carrying parts, connection strips etc., must be fully insulated in P.V.C. tape of the colours mentioned above. All outgoing leads shall be connected to a marked terminal strip.

4.15.11 Panels shall be fully labelled with black ivorine labels having 5mm high white lettering and riveted to the cover plates precariously referred to. Labels which are merely affixed with adhesive will **NOT** be acceptable.

4.15.12 All switch panels shall have phase failure, phase rotation and low voltage protection with automatic reset adjustable to a maximum period of 10 minutes.

4.16 FEED AND EXPANSION TANKS

4.16.1 Feed and expansion tanks shall be provided on hot water and chilled water installations to allow changes in density of this water to expand freely without damage to the piping systems.

4.16.2 Construction of the tanks shall be equal to Braithwaite sectional hot dip galvanised tanks, site assembled if necessary, with bolts and packings to their manufacturer's recommendations. Tops of the tanks shall be covered but a readily removable drop-in type inspection hatch shall be provided, the hatch complete with handles and vent.

4.16.3 Each tank shall also serve as water supply source for the system it is connected to and shall be complete with, but not necessarily limited to, the following fittings:

High pressure ball valve, with copper ball, 19mm for tanks less than 1800 litres, 25mm for tanks 1800 to 3600 litres and 38mm on larger tank capacities.

Quickfill valved connection, sized as for above ball-float valves.

Overflow and drain connections, 50mm pipe size for tanks up to 1800 litres capacity, 63mm size on 1800 to 3600 litres and 75mm pipe diameter for larger sizes.

Feed/expansion connection of 50mm pipe size for tanks up to 1800 litres capacity and 75mm on larger sizes.

4.16.4 Expansion tanks shall be sized by the air conditioning Subcontractor so that its contents between minimum level and full level are one-tenth of total water content of the system it serves. Minimum water level shall be 230mm from tank bottoms and expanded water level shall be 150mm below overflow connections.

4.16.5 Tanks mounted outside and exposed to the elements shall be insulated with 38mm thick heavy density fibreglass covered with 0,85mm galvanised sheetmetal jacketing and neatly finished, this applicable to tank sides only. The top of the tank need not be insulated but the bottom shall rest on 50mm thick hardwood planks suitably treated against rotting and insect attack.

4.16.6 Furnish sufficiently robust tank stands constructed of mild steel sections, the steelwork painted if indoor located and hot dip galvanised for exterior situations. Tank stands shall be complete with 450mm wide catladders where required to inspect water levels. Stands shall further comply with the relevant clauses on the Specification referring to Equipment Supports, refer clause 4.41.

4.17 WATER TREATMENT PLANTS

4.17.1 Evaporative cooling plants shall be provided with a chemical treatment plant which shall include chemical dosing to inhibit corrosion and scale formation and to protect the system against sludge formation and algae growth.

4.17.2 Cooling towers shall in addition, be provided with side stream sand filters with integral pump and backwash facility in order to filter the circulating water by drawing from the main distribution piping and returning the filtered water back into the system.

4.17.3 Closed circuit systems shall be treated with a chemical such as "Watergy 2753" or equal corrosion inhibitor and scale suppressant. The chemical treatment shall be applied only after the system has been flushed out and filled with clean water.

4.17.4 Subcontractors shall employ the service of a competent water treatment company regularly engaged in the water treatment to Air Conditioning Plant. The water treatment company employed shall provide all necessary service and operation training to ensure the efficient operation of the system.

4.17.5 Routine service of the water treatment plant shall be conducted at a minimum of 12 times during the guarantee period. The purpose of these service visits shall be to prevent potential problems from arising that will reduce equipment efficiency and result in equipment damage. Service reports shall be submitted to the Engineer detailing the work carried out at each service, problems encountered and what action was taken to rectify this.

4.17.6 The water treatment company employed shall have major laboratory back-up capabilities to assist in the solution of problems which may arise.

4.17.7 All water circuits shall include corrosion coupon monitoring with rates not to exceed 2,0 mls per year on mild steels.

4.17.8 Chemical dosing shall be automatic and the system shall include all necessary metering pumps, storage drums, conductivity monitor, bleed off control and all other appurtenances necessary for the efficient dosing and monitoring of the chemicals.

4.18 WATER PUMPS

4.18.1 Pumps shall be of the non-overloading, volute, centrifugal type, horizontal split, with bearing pedestals.

4.18.2 Volute casings shall be cast iron and overhung from heavy duty bearing pedestals. Casings shall have axial suction and radial discharge nozzles and shall be fitted with renewable case wear rings of spun cast iron.

4.18.3 Impellers shall be of the cast bronze radial type overhung and shall be dynamically balanced.

4.18.4 Shafts shall be chrome or stainless steel of sufficient diameter with withstand all stresses imposed and with a critical speed well above the maximum running speed. Shafts are to be supported axially and radially by two deep groove ball bearings built into the bearing pedestals.

4.18.5 Pumps are to be fitted with mechanical seals.

4.18.6 Pump casings shall be provided with an air vent cock at the highest point and a drain cock is to be provided at the lowest point.

4.18.7 Pumps shall be directly coupled to an electric motor which shall be of sufficient capacity to operate over the entire range of the pump without exceeding the motor power ratings.

4.18.8 Couplings between motors and pumps shall be by means of flexible couplings, "Fennerblex" or equal and approved. Couplings shall be provided with a removable galvanised sheet steel coupling guard, minimum 1mm thick, which shall be securely bolted to the bedplate of the pumps.

4.18.9 Characteristic curves for all pumps shall be stable over the entire operating range. Pumps shall operate at or near the point of peak efficiency, permitting operation at capacities approximately 25% beyond the design capacity without exceeding the break-off point. The subcontractor shall submit pump curves for approval with shop drawings and verify the system resistance, including pressure drops through all components, in order to establish the pump head. Pumping heads indicated under the Schedule of Equipment Capacities Required, are merely a guide for tendering purposes.

4.18.10 Pumps and motors shall be mounted on a baseplate of either cast iron or fabricated steel of ample size and strength to hold the total assembly in correct alignment. Suitable drip trays shall also be provided and the baseplate is to be filled with concrete.

4.18.11 A pipe shall be run from each drain point on each assembly and shall terminate with a suitable gap over the nearest floor drain.

4.19 WATER PIPEWORK

4.19.1 General

4.19.1.1 Water piping systems shall be run to general routes indicated on the relevant drawings. Piping shall be arranged to maintain headroom, keeping access ways unobstructed, allowing pipe routes not to interfere with maintenance and adjustment of valves and equipment. Piping should be installed at right angles, parallel to surrounding walls, plumb and of as direct routing as possible. Provide offsets where required to pass columns, beams or other structural features while maintaining headroom and proper clearance for insulation where relevant.

4.19.1.2 Where pipe sizes are not indicated on drawings, pipes shall be sized for a maximum water velocity of 2,5m/s within plantrooms and all other piping shall convey water at a velocity not exceeding 2m/s.

4.19.2 Piping Materials and Strength

4.19.2.1 Chilled water piping shall be seamless steel in accordance with specifications to the ASTM 106 or API 5L GRD B Schedule 40. Piping 50mm and smaller shall have screwed or welded joints. Piping 65mm and larger shall have welded or flanged joints.

4.19.2.2 Condenser water piping shall be galvanised to BS1387 or SABS 62 for pipes up to 150mm nominal bore, and SABS 719 for pipe larger than 150mm.

4.19.2.3 Pipes shall be galvanised in accordance with SABS 763.

4.19.2.4 Where pipework is fabricated, this shall be hot dip galvanised after fabrication. No welding of galvanised pipe shall be permitted.

4.19.2.5 All drainage piping and similar open vented systems shall be galvanised or copper.

4.19.2.6 Mains water supplies shall be hand drawn copper with capillary fittings. Suitable dielectric couplings shall be provided at junctions between copper piping and any galvanised material to prevent electrostatic action.

4.19.3 Fittings

4.19.3.1 Long radius bends shall be used wherever possible, elbows only being permissible where limited space dictates their use.

4.19.3.2 Reductions in pipe sizes shall be effected with reducing sockets, bushing reducers not being allowable for this purpose.

4.19.3.3 Threaded fittings shall be malleable iron to S.A.B.S. 509-1975 Specification or wrought steel to BSS 1740 as relevant.

4.19.3.4 Welded fittings shall be genuine butt-weld fittings to BSS 1740. No welding of threaded fittings shall be permitted.

4.19.3.5 Strainers, screwed Y-Type on pipe diameters up to and including 50mm, flanged Y-type for piping up to 200mm diameter and flanged pot type on larger sizes. Screens shall be fitted with extraction handles for easy removal.

4.19.3.6 Gate valves, screwed brass with brass trim to S.A.B.S. 776-1975 on pipe diameters up to and including 50mm and flanged on larger sizes.

4.19.3.7 Globe valves, screwed bronze with bronze trim on pipe diameters up to and including 50mm and flanged type on larger sizes.

4.19.3.8 Check valves screwed bronze swing check bronze trim on pipe diameters up to an including 50mm and for 65mm and above wafer type double door spring closing Non-slam.

4.19.3.9 All flanged valves to comply with B.S. 4504 or S.A.B.S. 1123.

4.19.4 **Vents and Drains**

4.19.4.1 At all high points of water systems fit Spirax type 05 or equal automatic air vents with integral check valves. Each air vent shall be preceded by a gate valve to allow maintenance of air vents. Automatic air vents shall ensure positive removal of all air from water piping systems. At all low points of the system fit 15mm ball valves with hose unions, these valves so located that the entire piping systems can be completely drained. Fit such drain valves also at all equipment to allow complete drainage.

4.19.5 **Flexible Connectors**

4.19.5.1 At all equipment connections to vibrating equipment, or where shown on the Drawings, fit flexible connectors equal to VIBRO-FLEX. All flexible connectors to have flanged joints and be capable of 875 kPa or 1,5 times the system working pressure, whichever is the higher value.

4.19.6 **Pipe Joints**

4.19.6.1 Pipe joints shall be neatly made, all pipe cuts properly cleaned and reamered. At all connections to equipment use flanged joints or conical face unions for smaller pipe sizes up to 38mm nominal bore. Incorporate sufficient flanged joints, or unions to be the foregoing limited sizes to allow dismantling of sections to pipework which can readily be handled by one tradesman and one unskilled assistant. Use screwed joints on galvanised pipework up to and including 100mm nominal size and black piping up to and including 50mm nominal size. Welding joints shall be made with proper welding sockets. On black piping all sizes may be welded; where galvanised piping is called for above 150mm diameter, use black piping with welded joints and hot dip galvanise after welding. Screwed joints on piping up to 50mm shall utilise P.T.F.E. jointing tape equal to 3-M manufacture; for larger screwed joints use hemp and Stag or equivalent jointing compound. Flanged joints shall include Klingerite gaskets or equivalent. Caulking of joints will under no circumstances be acceptable.

4.19.6.2 Flanges for pipe jointing to BS 4504 or S.A.B.S. 1123 - 1977

4.19.6.3 Welded joints shall be carried out by certificated welders to BS 2633.

4.19.7 **Protection during Installation**

4.19.7.1 Plug open ends of piping, drains, fittings and equipment connections in a workmanlike manner during installation of pipework to keep systems free of rubble, dirt and other foreign matter.

4.19.8 **Pipe Supports**

4.19.8.1 Pipework shall be supported as later specified herein, refer Clause 4.41, at the following maximum centres:

50mm diameter and smaller	3,0m
65 to 100mm diameter	4,5m
125 to 150mm diameter	6,0m
200mm diameter and above	8,0m

4.19.9 **Expansion and Contraction**

4.19.9.1 Pipework installation shall allow generous latitude for expansion and contraction, supports for this purpose being of the roller cradle type. No pipework shall cause any stress on any equipment due to the thermal movement, nor shall it bend or distort from such factors. Fit expansion joints of the bellow type as required to comply with the foregoing and where indicated on the Drawings.

4.19.10 **Flushing and Testing**

4.19.10.1 Piping systems shall be tested, by means of a hydraulic pump to twice the operating pressure of the systems or 700 kPa whichever is the greater. Where this is not permissible due to the relevant maximum allowable piping working pressure, piping shall be tested to the limits set by such maximum allowable working pressure to the Engineers approval.

4.19.10.2 The Engineer shall be notified at least 48 hours prior to commencement of the tests. The pressure test shall be witnessed and approved by the Engineer or his representative.

4.19.10.3 The Contractor shall be responsible for all testing required by State and local authorities or other statutory bodies as requested by the Engineer, or required by the Specification. The Contractor shall provide four sets of all test certificates, witnessed by the Contractor's Authorities, and Engineer's Representative, and detailed so as to identify the area tested.

4.19.10.4 Acceptance of a test by the Engineer will not relieve the Contractor of responsibility for proper materials and workmanship. It shall be the Contractor's responsibility to test all piping, valves, fittings and other items erected by the Contractor in accordance with the Local South African Standard.

4.19.10.5 The Contractor shall remove all safety valves, gauges, instruments and items which could be damaged by the test pressure and shall supply and install blanks, blinds or temporary fittings for testing. The Contractor shall remove blinds, blanks or temporary fittings and replace safety valves, gauges and items which could be damaged by the test pressure on satisfactory completion of the test.

4.19.10.6 The Contractor shall supply all test equipment and materials.

4.19.10.7 The Contractor shall be responsible for the removal of water used in flushing and testing from all piping systems, including attached equipment.

4.19.10.8 Where temporary lines are required for draining, these shall be supplied by Contractor and removed after use, leaving the area in its original condition.

4.19.10.9 Where removal of all moisture or special cleaning is necessary, the method may be specified as additional to any other procedure which follows.

4.19.10.10 All lines and attached equipment shall be thoroughly flushed and cleaned before testing, usually by washing with water. The Contractor shall supply and install temporary flushing screens on the upstream side of all equipment, and shall remove same on completion of flushing. The Contractor shall be responsible for the removal of all resulting debris from the premises.

4.19.10.11 During flushing, all flanged elbows etc., noted as being for flushing purposes will be removed by the Contractor until the flushing has been completed to the Engineer's satisfaction.

4.19.10.12 All such flanged elbows etc., will be re-installed after completion of flushing out and before hydrostatic testing.

4.19.10.13 The Contractor shall be responsible for any and all damage resulting from a test pressure more than ten per cent higher than specified by the Engineer. The Contractor shall supply a safety or relieve value which shall be used at the pressure source to protect systems under test. The Contractor shall be responsible for venting all sections of piping systems, vessels and equipment while flushing, testing and draining to ensure against their collapse by vacuum.

4.19.10.14 Variations of pressure and volume due to temperature changes will be taken into account by the Engineer during pressure testing and the Contractor will be responsible for measuring and recording the average ambient air temperature at the beginning and completion of any test to support any claim for pressure drop due to temperature change. Such temperatures may be checked by the Engineer by reference to an independent body.

4.19.10.15 In the event of a pipeline system failing a test, a new test shall be applied after repairs and corrections have been made. Under no circumstances may repairs and connections be made whilst the pipeline is filled with water.

4.19.10.16 After completion of repairs, the lines will be re-filled, vented, pressurised and tested, including any parts which may have passed a test but which, in the opinion of the Engineer may have been affected by the repairs.

4.19.10.17 The Contractor shall supply test pressure gauges which shall either be dual scale test type gauges, or, if single, indicating scale types, a second gauge shall be used immediately adjacent to the test gauge. Gauges shall be suitable for the maximum test pressure, with dials at least three inches in diameter. The maximum pressure capacity of the gauge shall not exceed twice the test pressure. Gauges shall be checked against a standard gauge.

4.20 PIPEWORK INSULATION

4.20.1 Chilled Water Piping

4.20.1.1 Chilled water piping shall be insulated with preformed sectional resin bonded mineral wool with a density of 160kg/m^3.

4.20.1.2 Insulation thickness shall be as follows:

Pipes up to 25mm diameter	30mm thick
Pipes 32mm to 150mm diameter	40mm thick
Pipes larger than 150mm diameter	50mm thick

4.20.1.3 Insulation shall be supplied with a factory applied canvas wrap and shall be provided with a vapour barrier by applying two coats of "FOSTER SEALFAS 30/36" or equivalent and approved and overcoated with "FOSTER VINYL VAPOUR BARRIER 30/42" or equivalent and approved.

4.20.1.4 Circumferential joints to the insulation shall receive one application of "FOSTER FOAMSEAL 30/40" or equivalent, to the full thickness of the insulation during erection to obviate lateral migration of moisture vapour along the pipe being serviced.

4.20.1.5 All points where pipe supports are used or where the vapour barrier is broken due to cut outs in the insulation, shall be sealed during erection with "FOSTER FOAMSEAL 30/45" or equivalent and approved.

4.20.1.6 All exposed piping shall be provided with 0,5mm thick aluminium sheet cladding over the insulation material. Bends shall be clad with lobster back covering of similar material. Valves and fittings shall be insulated and provided with aluminium cladding.

4.20.1.7 Black pipework shall be painted with primer and one coat undercoat paint prior to insulation.

4.21 FANS

4.21.1 **General**

4.21.1.1 Requirements under this heading apply to fans which are not integral parts of equipment designed and supplied as complete units by the manufacturers. Selection of fans shall be such that the operating point is as close as possible to the point of maximum efficiency. In addition, fans and motors shall be selected such that they are capable of supplying a minimum of 10% above the specified air volume.

4.21.1.2 System resistance shall be calculated by the Subcontractor to meet the requirements of selected equipment. The Subcontractor shall submit his selections to the Engineer for approval before ordering equipment. When selecting the fan, cognizance shall be taken of site altitude, system air temperature and air density at which the system duty shall be met.

4.21.1.3 Belt drives shall be designed for a minimum of 25% overload with no less than two matched belts being used. Belts shall be selected and installed in accordance with the BSS 790-1973.

4.21.1.4 Pulleys shall be of the adjustable speed taper-lock type and shall be accurately keyed to the shafts and shall be aligned before systems are put into operation.

4.21.1.5 Belt guards shall be provided in accordance with the Factories Machinery and Building Works Act 1941 as amended. The guards shall have a front screen of expanded metal and shall be arranged to permit oiling, use of tachometers and other testing and maintenance operations with the guard in place. All fan openings shall be provided with protective wire guards in accordance with the above Act.

4.21.1.6 Fan bearings shall be selected for a minimum of 200 000 (Two Hundred Thousand) h ours average life at the given duty.

4.21.1.7 Lubrication points for fan bearings shall be readily accessible and shall where necessary be extended to the outside of the face casing to permit lubrication of the fan without removal of the fan or appurtenances. Fan shafts and bearings shall be suitably protected from rust and corrosion.

4.21.2 **Centrifugal Fans**

4.21.2.1 Unless otherwise specified, centrifugal fans shall be of the backward curve blade type with single thickness shaped blades designed to give the fan a non-overloading characteristic.

4.21.2.2 Fan casings shall be fabricated from heavy gauge steel adequately reinforced and supported to provide a rigid structure and prevent drumming. Field joints shall be flanged and bolted with gaskets fitted between the flanges to render these airtight.

4.21.2.3 Shafts shall be steel with sufficient mass so that the critical speed of the wheel and shaft is well above the maximum permitted speed of the fan. Wheels shall be tightly fitted and keyed to the shafts.

4.21.2.4 Fan bearings shall be self aligning ball or roller type.

4.21.2.5 Fans shall be driven by an electric motor through a V-belt drive and mounted on an adjustable motor bracket which shall form part of the fan framework.

4.21.2.6 Vibration isolation shall be provided by means of spring isolators which shall be properly selected and installed in accordance with the manufacturer’s specifications.

4.21.3 **Axial Flow Fans**

4.21.3.1 Unless otherwise specified axial flow fans shall be inline direct driven type with motor mounted inside the fan housing.

4.21.3.2 Fan casings shall be constructed from galvanised mild steel having a thickness not less than 3mm and having galvanised mild steel flanges at each end, drilled for connections to mating flanges on ducting.

4.21.3.3 Fans shall be multi-bladed aerofoil type all of non-ferrous metal or polyester construction. A varying number of blades to suit the application shall be provided. The fans shall be provided with adjustable pitch blades indexed to permit field adjustment.

4.21.4 **Propeller Fans**

4.21.4.1 Propeller fans shall be direct driven, ring or diaphragm mounted as specified or indicated on the Drawings.

4.21.4.2 The impeller shall be constructed from roll formed galvanised steel or aluminium sheet and shall be statically and dynamically balanced.

4.21.4.3 Vibration eliminators, consisting or rubber in shear mounted between the fan assembly and ring or diaphragm, shall be provided.

4.21.4.4 Exposed fans shall be provided with a suitable wire guard mesh to meet the requirements of the Factories Machinery and Building Works Act 1941 as amended.

4.21.5 **Fan Volume Controls**

4.21.5.1 Volume control of axial and centrifugal fans shall be by means of proprietary vortex dampers.

4.21.5.2 Fans shall be capable of stable operation while varying the supply air quantities from maximum design rating down to 20%.

4.22 ELECTRIC MOTORS

4.22.1 All electric motors on the installation shall be of one make unless integral with the equipment served and shall not operate in excess of 1500 R.P.M. unless previously approved by the Engineers for specific applications. Motors, unless otherwise specified, shall be 380 volt, three phase, 50 Hertz for all sizes from and including 0,4kW upwards; smaller motors may be 220 volts, single phase, 50 Hertz.

4.23 All motors shall be of the totally enclosed, fan cooled type and have metric frame dimensions. Motors shall be quiet in operation to the full acceptance of the Engineers.

4.23.1 Three Phase Motors shall all be squirrel cage induction type, special high torque motors being used on high inertia loads such as large centrifugal fans, where otherwise excessively large motors, necessary to overcome driven equipment inertia, cause operation B.kW to be less than 70% of motor nameplate kW. Starting methods for three phase motors shall be as follows:

Motors up to 4kW	direct-on-line
Above 4kW	Star-delta started, provided that the starting current does not exceed three times the full load amperes.

4.23.2 Single phase motors shall be capacitor start, induction run type with built-in manual reset overload protection.

4.23.3 Nameplate rating of electric motors shall be at least 15% greater than required driven equipment brake drive losses duly accounted for, on motors below 15kW nameplate. On larger motors 10% margin shall suffice.

4.23.4 All switch panels shall have phase failure, phase rotation and low voltage protection with automatic reset adjustable to a maximum period of 10 minutes.

4.24 MACHINERY DRIVES

4.24.1 Direct drive couplings shall be of the non-lubricated type, rated at least 125% of driving motor horsepower and flexible to allow minor misalignment. "Pin-and-Push" type coupling shall not be used, all direct drive couplings being of FENAFLEX type FX as manufactured by Fenner or approved equal. Direct drives shall be accurately aligned using the appropriate instruments to within 0,25mm.

4.24.2 Vee Belt drives shall in no case consist of less than two belts and shall be selected in accordance with manufacturer's rating, plus one additional belt per drive. Sheaves shall be machined cast iron with Taperlock shaft bushes all equal to FENNER; aluminium pulleys will not be permitted. All drives on the installation shall be of the same make and of modern high-capacity belt section such as FENNER Alpha, Beta, etc., Vee-belts shall be fitted in matched sets only.

4.24.3 All drives shall be fitted with adequate drive guards complying with the relevant Government regulations, which guards shall totally enclose all moving parts. Drive guards shall be readily removable for access to the drives. Guards fitted to belt drives shall have an expanded metal fact to enable visual inspection of the drive without the need to remove the guard.

4.25 AIR FILTERS

4.25.1 General

4.25.1.1 Provide and install air filters in the positions as indicated on the Drawings and on all air handling plant providing conditioned air.

4.25.1.2 Filters shall be a standard product of a reputable manufacturer regularly engaged in the manufacture of the particular filter. The manufacturer shall submit evidence to the satisfaction of the Engineer, that the filters have been tested, by an independent South African Authority and that they meet the minimum arrestance efficiency and dust holding capacity specified.

4.25.1.3 Filters shall be tested in accordance with the A.S.H.R.A.E. Standard 52-76 Gravimetric on primary and Opacimetric on secondary and tertiary filters.

4.25.1.4 The systems resistance for selection of fans shall make allowance for resistance of the filters at 80% of the recommended final filter resistance.

4.25.1.5 Manometers shall be provided across each filter bank and shall indicate filter resistance. The clean and change out resistance of the filter shall be clearly marked on the manometer.

4.25.2 Primary Air Filters

4.25.2.1 Primary air filters shall, unless otherwise specified, be washable non woven polyester material, pleated to provide an extended surface with an efficiency of 88%, Gravimetric.

4.25.2.2 Media shall be firmly held in place by rust proofed wire screens to maintain pleat strength and spacing.

4.25.2.3 Media and support screens shall be continuously bonded into aluminium support frames folded to form a robust media support frame. The bonding between media and frame shall be continuous to prevent leakage.

4.25.3 Secondary Filters

4.25.3.1 Secondary filters shall, unless otherwise specified, be of the pocket type manufacture using fine filament, non-woven, polyester media constructed in such a manner so as to withstand vacuum cleaning.

4.25.3.2 Media shall be supported to expose the greatest effective area to air flow and to promote uniform dust loading. The filter shall maintain its rigidity under all flow conditions from maximum air flow to no air flow. This being particularly important on Variable Air Volume systems.

4.25.3.3 Secondary filters shall have an efficiency of 65%, Opacimetric

4.25.4 **Tertiary Filters**

4.25.4.1 Tertiary filters shall be of the high efficiency HEPA type contained in a solid frame with seals which ensure the integrity of the filter without bypass.

4.25.4.2 Media shall be supported to expose the greatest effective area to air flow and to promote uniform dust loading. The filter shall maintain its rigidity under all flow conditions from maximum air flow to no air flow. This being particularly important on Variable Air Volume systems.

4.25.4.3 The supply air fan on all systems with tertiary filters shall be capable of providing the specified air volume with all filters dirty. The fan shall be provided with a speed controller to automatically maintain the specified air volume at all times. The control shall be achieved through a velocity sensor in the supply airstream.

4.25.4.4 Tertiary filters shall have an efficiency of at least 99.999% at 5µ.

4.25.4.5 After installation of the filters, the system shall be validated by an approved testing authority using equipment with a valid calibration certificate.

4.25.4.6 Tertiary filters shall always be installed downstream of the fan and any other system equipment and as close as possible to the supply terminals.

4.25.5 **Filter Handling Frames**

4.25.5.1 Each filter cell shall be provided with a factory made holding frame, constructed of not less than 1,00mm thick stainless steel grade 304 or powder epoxy coated galvanised steel. On primary and secondary filters, a quick release spring type clip shall securely hold the filter cell in place without permitting leakage of air. The holding frames of multiple cell filter banks shall be suitably joined and sealed so as to prevent the leakage of air between the frames.

4.25.5.2 The frames shall ensure that the filters can be accessed for removal and replacement, either side access or rear access

4.26 COOLING AND HEATING COILS

4.26.1 Heating and Cooling water fed coils shall be of the serpentine form, extended surface type with cast iron, brass or copper supply and return headers with inlet, outlet, vent and drain connections on the same end of each coil.

4.26.2 Tubes shall be fabricated from not less than 16mm diameter copper or brass tubing having a wall thickness of not less than 0,5mm and shall be soldered or brazed into the pipe headers unless the headers are thick enough or provided with bosses heavy enough to withstand, without distortion, the stresses imposed due to rolling or expanded the tubes into the headers. Pressure parts of the coils shall be constructed and tested for a working pressure of not less than 1350 kPa.

4.26.3 Fins shall be of the helical or plate type spaced at not less than 12 fins per 25mm (2,12mm centres or 470 fins per meter) for aluminium fins and at not less than 8 fins per 22mm (3mm centres or 333 fins per meter) for copper fins. Helical fins may be crimped or tapered. Crimped fins shall have a nominal thickness of not less than 0,18mm and shall be soldered to the tubes. Tapered copper fins shall have a thickness of not less than 0,2mm at the base and shall be soldered to the tubes or wound with sufficient tension to ensure a permanent bond. Plate type fins may be flat or formed and shall have a nominal thickness of not less than 0,13mm for copper and 0,2mm for aluminium. Plate fins shall be soldered to

the tubes or shall be provided with integral spacing collars at least 3mm wide, or full width of fin spacing if this is less than 3mm, into which the tubes shall be tightly and permanently expanded.

4.26.4 Casings shall be constructed of not less than 2,0mm thick galvanised steel and shall be provided with drilled flanges for bolting to other coil sections or to unit casings. Coil sections having a tube length in excess of two meters shall be fitted with centre braces for tube support and casing rigidity. Multi-coil assemblies shall be supported on hot dipped galvanised steel channel frames. Such supports shall not pierce the drip pans and shall be arranged so that condensate cannot run down them past the drip pans. Flanged sections between coils shall be sealed and covered with 1,0mm thick galvanised sheet metal flashing to prevent air bypassing between the sections and each complete coil assembly shall be installed so that no air bypasses around the edges of the casings.

4.26.5 Condensate drain pans shall be fabricated from 1,6mm thick galvanised sheet steel riveted and soldered and sloped to drain all condensate. A pan shall be installed below each coil and the drain pans of multi-coil assemblies shall be provided with galvanised pipe connections through each drain pan to the lowest drain pan, from whence the condensate shall be piped to the drain point to be provided by others. Drain pans shall be extended 50mm beyond the coil casings on the leaving air side. All condensate drain pans shall be insulated and vapour sealed on the underside to prevent the formation of condensation. The insulation material and adhesive shall be non-combustible.

4.26.6 Eliminators shall be provided on the fan side of cooling coils if there is any possibility of water droplets being carried over into the fan chambers. Such eliminators shall then be designed to eliminate all condensate from the air stream and shall be fabricated from extruded sheet plastic and shall be sectionalised to facilitate maintenance. Should it be necessary to install eliminators then the drip pans shall be extended to drain condensate removed by the eliminators. If eliminators are not provided for by the Tenderer, then the Subcontractor shall provide the Engineer with a written guarantee that no moisture will be carried beyond the drip pans under the operating conditions for which the coils are to be selected.

4.26.7 Sumps for sprayed coils shall be as later specified herein.

4.26.8 Coils shall be suitably protected during shipment and installation so that fins and casings are not damaged. Coils having loose or damaged fins at the time of the final inspection shall be replaced if considered necessary by the Engineer.

4.27 SPRAYED COIL ASSEMBLIES

4.27.1 Sprayed coil assemblies shall be factory manufactured and assembled units of a specialist equipment manufacturer and shall each comprise of the following components contained within or forming part of the casing of the self-contained Sprayed Cooling Coil units which shall be installed in the positions indicated on the Drawings and shall be supplied with treated water from the water treatment plant located in the Sub-Basement Plant Room.

Chilled water fed cooling coil, as previously specified herein,

Recirculated water sump,

Inlet air baffles,

Spray nozzles with associated piping,

Air outlet drift eliminators.

4.27.2 The cooling coil shall be as previously specified in Clause 4.26 of these Specifications and shall be installed within the sprayed coil unit casing assembly so as to prevent air and water bypassing around the perimeter of the coil casing.

4.27.3 The water sump shall be constructed of hot dip galvanised steel of 3mm minimum thickness, reinforced as necessary to carry the weight of the cooling coils, eliminators, etc., and further rust proofed with a

suitable and approved epoxy resin based sealer. The sump shall be suitably insulated with 12mm minimum thickness of factory-applied polyurethane foam. The sump shall be 75mm minimum deeper than the working water level.

4.27.4 Sump fittings shall include the following items, all connections to the sump being made by the use of pipe sockets welded into it before the sump is galvanised.

A suitable anti-cavitation pump suction connection,

A removable copper mesh pump suction screen,

A 20mm NB ball-float valve of the high pressure type, complete with 200mm diameter copper ball and 20mm NB drain and overflow connections.

4.27.5 On the air inlet side of the sprayed coil unit shall be fitted 0,6mm thick galvanised sheet steel suitable rustproof coated, or extruded sheet plastic, air inlet baffles spaced at not exceeding 75mm centres. The baffles shall be suitably stiffened and bent at both the leading and the trailing edges and shall be horizontally arranged in sections and be readily removable for replacement. NO spray water shall pass through the baffles when the spray washer is tested with no air flow through it.

4.27.6 Between the air intake baffles and the cooling coil battery, provided the spray washer system of the unit. The spray washer shall be of the single bank type utilising one set of nozzles spraying in the direction of the air flow.

4.27.7 The spray header to the nozzles shall consist of one horizontal inlet pipe with its inlet water connection welded into one side of the sump. Vertical standpipes shall be fitted to this header with a suitable number of small bore pipe branches being fitted to the former for attachment of the spray nozzles. All pipework within the spray chamber shall be galvanised, as also shall be any pipe supports required.

4.27.8 The spray nozzles shall operate at a pressure of 50 kPa and handle the correct water quantity as called for in the detailed Specifications. The spray nozzles shall provide coverage of the entire coil face area. All nozzles shall be 10mm NB diameter inlet and of the brass "non-clog" type with removable orifice caps.

4.27.9 On the air leaving side of the cooling coil battery a set of vertical drift eliminators are to be installed, these eliminators to have a minimum of three bends and to be of identical construction and finish to the air inlet baffles, a minimum of 300mm in overall length in the direction of air flow and spaced at 75mm maximum centres. The eliminators shall be supported between notched hot dip galvanised or extruded plastic angles on leading and trailing edges and so arranged that no spray water shall be allowed to pass them into the air stream under a test air velocity of 3 meters per second. The eliminators shall be readily removable for access to the cooling coil or for purposes of replacement.

4.27.10 The casing shall be suitably stiffened at the air entering and leaving ends and be constructed of not less than 1,6mm thick galvanised steel sheet rustproof paint-coated and braced and framed with hot dip galvanised steel angles. The casing shall be fixed to the sump below it by means of flanges, cadmium plated bolts and a suitable water-resistant gasket. All seams in the casing shall be adequately sealed with mastic or similar non-hardening substance. Suitable access provisions shall be allowed in the casing for sufficient access to the spray nozzles for servicing purposes, unless the air inlet baffle assembly already affords such access.

4.27.11 The complete unit shall be installed on a reinforced concrete base provided by others. Between the sump of the unit and the concrete base, lay a 50mm thick layer of good quality steam-baked cork insulation and properly vapour proof same with bitumen applied hot. The base shall be pitched towards the drain connections on the unit, to facilitate drainage and cleaning and the drain connection shall be piped to the drain point to be provided by others in the Plant Rooms, in the positions indicated on the Drawings.

4.28 ELECTRIC HEATER BATTERIES

4.28.1 Electric heater elements shall be factory-bent type so arranged that all connections are on the same side. They shall be black heat, 5W/cm rated for still air operation by their manufacturers but operated at a minimum air velocity of 5 meters per second on this project. Elements shall be rated for 250 volt site electricity supply, with consequent lower wattage heat output and lower sheath temperature. Arrangement of heater elements within the heater batteries shall be such that they are uniformly spaced across the width of the duct to present equal air flow over each element. When necessary arrange in staggered rows to ensure best distribution of air flow over individual elements.

4.28.2 Heater elements shall be fitted into a frame attached to a terminal box, the frame fitted into a rectangular opening on one side of the duct. The frame shall be constructed of 1,6mm bent-up galvanised sheet steel channel and the terminal box, frame and heaters assembly shall be readily withdrawable from the heater casing.

4.28.3 Terminal boxes shall be fabricated from 1,2mm galvanised sheet and fitted with a hinged cover fabricated from 15% free area flattened expanded mesh to allow adequate ventilation. No screws, fixings or sharp edges shall project into the terminal box; the hinged terminal cover shall however be secured with clip type fasteners. All wiring within the heater terminal box shall be carried out with silicone insulated stove cable wired to a porcelain terminal strip to which incoming P.V.C. insulated cables are also to be connected. Connections for looping wiring within the terminal box shall be executed with porcelain connectors.

4.28.4 Ductwork attached to heater batteries shall be insulated internally with 6mm asbestos millboard for 500mm on air inlet side and 1000mm on air leaving side, if space permits. Such asbestos shall be fitted over any other internal duct insulation that may be required and the rough edges shall be fitted with galvanised sheet metal covers, riveted to the ductwork, to prevent entrainment of loose fibres into the air stream.

4.28.5 Heater batteries shall be protected against overheating with fire safety thermostats of the manual reset rigid tailstock type sensing temperature in ductwork on the leaving air side of the battery. Thermostat locations shall be such that their operation is unaffected by radiation from the heater elements and their temperature setpoint shall be 55ºC. Thermostats shall have single pole double throw contact arrangement to enable trip condition to be indicated by means of pilot lamps on the relevant electrical switchpanel.

4.28.6 All air handling plants fitted with electric heater batteries shall be so automatically controlled that when the plants are shut down, the operation of heater elements is stopped, but fans shall continue to operate for 3 minutes before shutting down, all to cool off heater elements for prolonged life, as well as to prevent false tripping of fire protection thermostats. Under alarm signal control conditions for shutting down the plants, the fans shall be isolated immediately.

4.28.7 All heaters shall be installed from the top of the ducting where at all possible.

4.29 HUMIDIFIERS

4.29.1 Humidifiers shall have the capacities as called for in the detailed specification.

4.29.2 Humidifiers shall be of the packaged type consisting of submerged resistance heating elements contained in a stainless steel vessel. The container shall be cleanable by means of a removable lime collecting bag. The unit shall be completely automatic in operation and shall include an automatic self flushing system which shall be adjustable to suit the different water conditions. All switching sequences shall be by means of solid state switching.

4.29.3 Steam output shall be adjustable in response to an external automatic control signal. This proportional response must be instantaneous and is to be achieved without boildown or dumping of hot water. Proportional control must be from 0 to 100% variable.

4.29.4 Humidifiers shall be installed in full accordance with their manufacturer's instructions and have their steam injection nozzles fitted in the positions indicated on the Drawings.

4.29.5 Humidifiers shall be piped to suitably selected steam injection nozzles each being of sufficient length so as to extend over the full length of the coils or the ducts, or be the maximum standard length available from the manufacturers of the humidifiers, and positioned for optimum mixing of the steam discharge with the air without condensate forming on any adjacent casings or inside the supply air ducts. Should steam distribution hosing runs, because of their length, cause excessive steam temperature drop and a consequent high rate of condensate within them, then the hoses shall be insulated with suitably sized light density, preformed fibreglass sectional lagging covered with P.V.C. plastic sheeting overlapped over each section and fixed with approved adhesive, as previously specified herein for the insulation of all hot water piping.

4.29.5.1 Each humidifier shall be supplied with two sets of spare replaceable lime collecting bags.

4.29.6 Water connections to and drain connections from the humidifiers shall be carried out in water quality copper tubing using SECUREX or equivalent compression type fittings. The mains water serving the humidifiers must NOT BE TREATED and shall be taken from the mains water supply connections to be provided by others in each plant room in the positions indicated on the Drawings.

4.30 DUCTWORK

4.30.1 Ductwork shall be carried out in accordance with the details shown on the relevant Drawings and be fabricated from prime quality galvanised sheetmetal, except where otherwise called for. Where duct sizes are shown on the Drawings, such dimensions are metal sizes and to include the necessary allowances for any internal insulation which may be specified.

4.30.2 Ductwork shall be fabricated and installed in accordance with the duct construction and installation standards as detailed in the HVAC DUCT CONSTRUCTION STANDARDS - METAL AND FLEXIBLE - latest edition as issued by SMACNA (Sheet Metal and Air Conditioning Contractors National Association, Inc. of America) or SANS 1238.

4.30.3 Unless otherwise specified or allowed, main ducts shall be constructed to a minimum of 100mm wg. and branch ducting to a minimum of 50mm wg.

4.30.4 Fittings such as elbows, parallel flow branches, branch connections, off-sets and transitions shall be manufactured and installed in accordance with the SMACNA standards.

4.30.5 All ducting shall be sufficiently airtight to ensure economical and quiet performance of the system and joints shall be suitably sealed in accordance with the relevant SMACNA standards with suitable non-combustible filler compound or adhesive tape applied in accordance with the manufacturer's instructions and to the Engineer's approval.

4.30.6 Access doors shall be provided where indicated or required for inspection, maintenance, and replacement of all instruments, controls and other equipment. In particular, access doors shall be provided at all Fire Dampers, Automatic Dampers, Main Balancing Dampers, Filter Banks, and at the inlet and outlet sides of Axial type fans.

4.30.7 Access doors, where possible, shall be a minimum of 500mm x 500mm square. Where access doors are provided to items of plant these shall be as large as possible to permit access to the plant for maintenance and removal of equipment.

4.30.8 Access doors shall be constructed in accordance with the SMACNA standards and shall be installed in a reinforced frame to ensure that the door is airtight. Access doors shall be hinged and held in position by means of a minimum of two Sashlocks or Camlocks. Where access doors are intended for main access, the locking mechanism shall be capable of operation from both sides of the access door.

4.30.9 Duct connections to vibrating equipment shall consist of a flanged joint, followed by a flexible connector consisting of a fire retardant PVC covered cloth affixed on either side of the joint and a double lock seem to form an airtight flexible joint with a minimum of 50mm separation between metal edges. Ducting at

flexible joints shall be so supported that the ductwork is held square with the adjoining duct and no stress is imposed upon the flexible joint.

4.30.10 Test holes, where provided in ductwalls for admission of testing apparatus, shall consist of a suitable opening having a self-sealing Neoprene rubber grommet.

4.30.11 Flexible ducting shall be coated fibreglass fabric mechanically locked to a galvanised flat steel helix, "Kopes" or equal. The material shall be non-flammable and shall meet the requirement of the fire authorities having jurisdiction.

4.30.12 Flexible ducting shall be suitable for the operating temperature and pressure and shall be secured to spigots by means of circular "Jubilee" securing bonds making air tight connections.

4.30.13 Flexible ducting shall be installed with "easy" bends of not less than one duct diameter centreline and shall be supported to SMACNA specifications to ensure that ducting does not kink. The length of flexible ducting shall be kept to a minimum and shall not exceed lengths of 1200mm.

4.31 DUCTWORK AND PLENUM INSULATION

4.31.1 Ductwork shall be insulated according to the requirements as indicated on the Drawings and in accordance with the following specification.

4.31.2 Internal duct lining shall, unless otherwise specified, comprise 25mm thick 24gk/m^3 density, 8% resin content bonded fibreglass cloth, SONIC LINER, or equal, glued to the inside surface of the ductwork with a fire retardant adhesive equal to EUROPAIR'S EUROBOND self-extinguishing adhesive, the butting edges of the insulation first heavily caulked with FOSTER'S 60-30 mastic, or equal, to seal them. Additionally, the insulation shall be mechanically secured with GRIP NAILS or WELDPINS at 400mm centres and not more than 75mm from the edges of each panel. Insulation ends shall be covered with 0,85 thick galvanised sheet metal strip riveted to the duct panels to prevent the erosion of particles of insulation into the air stream.

4.31.3 Any insulation of which the facing has been damaged shall be properly patched with FOSTER'S 60-30 mastic and fibreglass cloth.

4.31.4 Externally insulated concealed ductwork shall be insulated with 50mm thick, minimum 18kg/m^3 8% resin content bonded fibreglass blanket faced with a fibreglass scrim reinforced aluminium foil kraft facing. The insulation material shall be wrapped around the ductwork and sealed at the joints which shall overlap and be covered with a 50mm wide aluminium foil tape, to ensure vapour proofing.

4.31.5 The insulation shall be applied to the ductwork with EUROPAIR'S EUROBOND or equal, self-extinguishing adhesive and be mechanically secured with 20mm wide aluminium bands strapped around ducting at regular intervals of not more than one meter centres.

4.31.6 Externally insulated exposed ducting shall be insulated with 25mm thick minimum 64kg/m^3 density, 8% resin content, bonded fibreglass batts evenly secured to the ductwork, with EUROBOND adhesive and WELDPINS at 400mm centres, and covered with wire mesh securely attached and plastered to a smooth finish with not less than 12mm thick hard setting compound. All corners shall be neatly rounded off and the finished surface shall be painted as later specified herein for exposed ductwork in Plant Rooms.

4.31.7 Flexible ducting shall be insulated with 25mm thick 12kg/m^3 resin bonded insulation wrapped with a P.V.C. sheath.

4.31.8 External insulation to ductwork and plenum insulation as specified herein shall be undertaken by a firm of specialist insulation contractors employed by the air conditioning Subcontractor, costs for their work being duly allowed for by the air conditioning Subcontractor in his Tender Price. The air conditioning Subcontractor will be held fully responsible for the work of his insulation Subcontractor in all respects.

4.31.9 Exhaust and outside air intake ducting shall not be insulated.

4.32 DAMPERS

4.32.1 Provide dampers where shown on the Drawings, where necessary for shut-off, bypass or volume control purposes, and where required to comply with local fire codes, as relevant.

4.32.2 Volume control dampers shall consist of multiple extruded aluminium aerofoil blades acting in opposed blade fashion with aluminium gears. The blades shall be fitted with rubber sealing strips on their edges and shall be robustly linked together to operate in complete unison. Permanently set dampers shall be provided with suitable devices to facilitate locking them in position such device to consist of a quadrant with "Open" and "Shut" position indication.

4.32.3 Motorised dampers shall include suitable fastenings and supports for motor actuators. The damper blade axle shall be mounted in the damper frame on suitable roller bearings to provide free movement of the blades.

4.32.4 Damper hardware shall be the product of an accredited manufacturer of such items, equal to EUROPAIR. Entire damper sections shall be housed in flanged sheet metal casings of 1,6mm thick galvanised steel. No damper blade shall exceed 200mm in width. Dampers over 900mm blade length shall be sectionalised into separate cells each with its own shafts and bearings to ensure that blade length of each section does not exceed 900mm.

4.32.5 Splitter dampers shall be equal to Titus type AG-45 Air Volume Extractors with No. 2 duct regulator to enable adjustment without access into the duct. Entire installation of splitter dampers shall be such that they do not vibrate or rattle due to air movement over them.

4.32.6 Non return dampers shall be provided as specified or indicated on the Drawings and in all installations where fans are mounted in parallel. The dampers shall be constructed of rigid aluminium blades of not less than 2mm thickness and shall be constructed in accordance with the SMACNA specifications. The non return dampers shall open by means of air flow and close by back draught and shall be free from vibration and rattling.

4.32.7 Fire dampers shall be manufactured to a recognised fire code for a two-hour fire rating. Damper casings shall have flanged ends and single blade units applicable to rectangular ducts, and shall not exceed 300mm blade width. The fire dampers shall further be specialist manufactured by an accredited firm in this field and shall additionally comply in all respects with the requirements of the local municipal fire authorities, in the area where they are to be installed and S.A.B.S. 193-1972.

4.32.8 Damper blades shall be closed by the operation of approved fusible links located where they would be immediately affected by an abnormal rise of temperature of the air stream. When specified in Part Five of the Specifications the blades shall also be actuated by 24 volt D.C. solenoid operators which shall be provided by the damper manufacturers. When closed the blades shall be held by a catch arrangement so as to provide a positive seal against the air stream.

4.32.9 All dampers installed in ducts shall be provided with an inspection opening so that the dampers may be checked and maintained. Inspection openings shall be covered with suitably sealed access panels.

4.32.10 Smoke dampers shall be the product of a specialist manufacturer in this field, built to an acknowledged standard such as Underwriters Laboratories and be smoke tight against an air pressure of 50mm wg. They shall be actuated by 24 volt D.C. Solenoid operators which shall be provided by the damper manufacturers. When closed the blades shall be held by a catch arrangement so as to provide a positive seal against the air stream. Adequate access provisions shall be incorporated in adjoining ductwork to allow resetting of dampers which have tripped.

4.33 SOUND ATTENUATORS

4.33.1 Sound attenuators shall be provided and installed in the positions indicated on the Drawings and shall be selected to provide the Noise Criteria levels as further specified herein. All sound attenuators shall be the

factory fabricated product of an accredited manufacturer of such equipment, such as I.A.C. (International Acoustics Company), DONKIN or TROX, who publish selection data on their products, which data shall be submitted to the Engineers for approval of each sound attenuator offered.

4.33.2 Metalwork on sound attenuators shall be galvanised steel or aluminium and acoustic insulation shall be non-combustible material, properly bonded and covered so as not to permit insulation particles being eroded by air movement over them.

4.33.3 Sound absorbing lining material of sound attenuators in low velocity ductwork shall have a density of not less than 24kg/m^3 and a thickness of not less than 25mm and in medium pressure ductwork the thickness shall not be less than 50mm with a minimum density of 48kg/m_3. Material for cell type sound absorbers shall be of the rigid type. The sound absorbing efficiency at each frequency shall not be less than;

Frequency-cycles per second	250	500	1000	2000	
Percentage Absorption		45	65	70	80

4.33.4 All lining which is damaged in shipment or due to exposure or any other cause shall not be installed and any material which may be damaged prior to the final acceptance shall be replaced as directed by the Engineer.

4.33.5 Casings shall be manufactured of galvanised sheet steel not lighter than the thicknesses previously specified herein for ductwork of the same dimensions, for the various pressure systems.

4.33.6 Kitchen extract ducting sound attenuators shall be either PACKLESS as manufactured by the International Acoustics Company, or equal and shall be suitably treated to the unaffected by the build up of grease which will occur on the attenuator.

4.34 AIR TERMINALS

4.34.1 Air distribution shall be effected by means of grilles or diffusers of the sizes, types and having the discharge patterns as indicated on the Drawings.

4.34.2 Tenderers must reselect grille and diffuser sizes if, for the makes offered, the dimensions called for on the Drawings do not provide for sound power levels later specified herein in Section Seven hereof, when handling the required air volumes.

4.34.3 The Subcontractor shall liaise and co-operate with the firm appointed for the installation of the ceiling, who shall undertake the final lining-up and levelling of the diffusers which shall be installed in conjunction with the ceiling to form an integrated, compatible and acceptable unit.

4.34.4 The finish of all grilles, diffusers and louvres shall be epoxy powder coated, baked enamel or colour anodised, the colour being to the Owner's or Architect's choice of colour, to be advised and approved by the Engineers.

4.34.5 Grilles and diffusers shall be fixed to spigots extended not less than 100mm from the ducting, unless otherwise indicated on the Drawings, and shall be securely fixed so that no screws or other fixing devices are visible.

4.34.6 Supply air grilles shall, unless otherwise specified or indicated on the Drawings, be of the double deflection type consisting of two rows of individually adjustable aerofoil section vanes, front vanes being horizontal, rear vanes vertical, all vanes housed in a surrounding fixing flange with neat mitred joints at the corners. The entire grille assembly shall be of extruded aluminium construction.

4.34.7 All supply air grilles shall be complete with factory fitted opposed blade dampers as later specified herein.

4.34.8 Supply air diffusers shall be of steel or aluminium construction and shall consist of an inner section which is readily removable from the outer core to facilitate access to the control dampers to be located behind the diffusers as later specified. The inner section of the diffusers shall consist of concentric rectangular or circular collars, the outer section consisting of a single rectangular or circular bevel collar provided with concealed fixing devices for attaching it to the supply air ductwork.

4.34.9 Supply air grilles and diffusers shall be provided with multivane opposed blade dampers finished in matt black lacquer. The dampers shall be attached to the rear of the grilles and fitted into the spigot connections to the diffusers and shall be adjustable, by means of a key or lever, from the front of the installed grilles and diffusers.

4.34.10 Return air grilles shall, unless otherwise specified or indicated on the Drawings, consist of aluminium grid core housed in an extruded aluminium fixing flange with neat mitred corners and finished in anodised aluminium to match colour sample to be supplied by the Engineer.

4.34.11 Return air grilles shall be equal to TITUS model 50 F with a 12mm grid core.

4.34.12 Transfer grilles shall be of extruded aluminium construction equal to TITUS model T-700-B grilles fitted to timber frames, to be provided by others, on both sides of openings through walls or partitions thicker than 50mm, alternative standard door grilles may be used with the grille installed on the "public" side and the auxiliary frame installed from the other side.

4.34.13 Door grilles shall be of extruded aluminium construction equal to TITUS model CT-700-BF suitable for fitting into doors of varying thickness and shall be finished in anodised aluminium.

4.34.14 Outside air intake weather louvres shall be of the extruded aluminium fixed vane type fitted with a vermin proof screen on the rear side as well as an opposed acting damper.

4.34.15 Dampers shall be provided with a locking device so that once they have been set for the correct air flow quantity they can be permanently locked in position. Louvres shall be finished in anodised aluminium.

4.34.16 Where indicated on the Drawings the outside air intake weather louvre assembly shall be fitted with filter holding frames with firmly fixed foam rubber gaskets and spring type clips for the attachment of the fresh air filters, as later specified herein. The frames shall be fixed to the weather louvre so as to prevent any air bypassing the filters.

4.34.17 Volume control opposed blade dampers shall be installed where noted on the Drawings. The dampers shall be as previously specified herein in Clause 4.32.

4.34.18 Rubber gaskets shall be glued to the rear of the fixing flanges of all air grilles, diffusers and louvres to ensure airtight seals and prevent smudging.

4.35 CANOPIES AND GREASE ELIMINATORS

4.35.1 Canopies and grease eliminators shall be the make of specialist in this field and shall not be manufactured by the Subcontractor. Canopies shall be equal to CYCLO-Wash or CYCLO-VENT with CYCLO-CLEAN grease filters and shall, unless otherwise specified, be constructed from 1,2mm thick grade 304 stainless steel with a number 3 finish.

4.35.2 Joints and seams shall be of welded construction and be watertight and all exposed welds shall be ground and polished to the original finish of the material.

4.35.3 Grease filters shall contain a series of vertical baffles to change the direction of the air flow and efficiently divert grease particles out of the air stream by centrifugal action. Each filter bank shall contain a condensate trough and removable grease storage container.

4.35.4 Fire Dampers, operated by fusible links, shall be provided in each air outlet connection and shall form an integral part of the canopy construction.

4.35.5 Lights shall be fitted into the canopy construction by the manufacturer.

4.35.6 Canopies having a length of less than 1300mm shall be provided with one, flush mounted, incandescent 100 watt, light fitting opposite each air intake. The fittings shall be square and recessed and shall consist of a steel housing with baked reflective white enamel finish, stainless steel exposed trim and diffuser of tempered glass with prismatic interior. Access for bulb replacement shall be through the face of the fitting without the use of tools.

4.35.7 Canopies having a length of more than 1300mm shall be provided with one flush mounted two lamp fluorescent light fitting opposite each air intake for every 2000mm of canopy length. The fittings shall have a steel housing with baked reflective white enamel finish, stainless steel exposed trim and diffuser of tempered glass with prismatic interior. Access for tube replacement shall be through the face of the fitting without the use of tools.

4.35.8 Canopies installed in the public view shall in addition be fitted with a 12,5mm square aluminium grid core shall be supported on a 25mm return on the inside edge of the canopy and shall be fitted in 600mm wide sections and be easily removable for cleaning.

4.35.9 Wet type canopies, equal to CYCLO-WASH shall be provided complete with control panel to provide automatic operation of the exhaust and make-up air blowers in addition to the wash and run cycles of the ventilator.

4.35.10 Control panels shall be constructed of 1,4mm thick galvanised steel and the front frames, doors and exposed trim shall be fabricated of 1,2mm grade 304 stainless steel having a number 3 finish.

4.35.11 Operation of the control sequence shall be initiated by front panel push button switches with individual wash and run indicator lights. An additional front panel indicator light and buzzer shall provide a warning in the event of a low detergent condition. Each control panel shall contain a hand shut-off valve, line strainer, solenoid valve and union connections for the hot water line. The detergent pump shall be capable of being adjusted to inject the proper amount of detergent into the hot water line.

4.35.12 Hot and cold water connections shall be provided adjacent to each wet type canopy by others, each connection shall be terminated within two meters of the canopy in an isolating valve. The Subcontractor shall allow for all necessary pressure reducing valves, filters and appurtenances necessary for the efficient operation of the system. Drain connections shall be provided by others within two meters of each canopy.

4.36 AUTOMATIC CONTROLS

4.36.1 Provide, install and set into operation all the automatic control devices shown on the relevant Diagrams and interlock same as required to perform their function correctly. The Subcontractor shall note that the various controls shown on the Drawings and as mentioned herein indicate the basic control elements and functions required only; they shall additionally furnish all ancillaries necessary to fulfil the desired plant operation.

4.36.2 Automatic control valves shall have bodies, discs, stems and sealing gland designed for not less than 1600 kPa operating pressure. Valves 40mm and smaller shall be gunmetal with union ends and machined seat. Valves 50mm and above, shall be cast steel with flanged connections. The sealing gland shall be of the double O-ring type permitting replacement without removing the valve. Spindle and plug shall be stainless steel.

4.36.3 Automatic valve and actuators shall be supplied separately, the assembly of which shall be done without the need for special tool or adjustment. Valves shall be opened by the actuator and closed by means of a return spring. A visible position indicator shall be provided. The actuator shall permit manual operation at the valve.

4.36.4 Automatic damper actuators shall be electro-thermal or electro-hydraulic, to suit the load requirements, linear stroke actuators with overload protection and spring return. The stroke of the push rod shall be controlled such that the stroke corresponds proportionally to the control signal.

4.36.5 Automatic valve and damper actuators shall be controlled by means of an electronic controller.

4.36.6 Electronic controllers shall be suitable for the application intended and shall provide P, PI or PID control as selected. The controller shall incorporate a manual/automatic switch. In addition, the P band and dead zone shall be adjustable. A plug-in service testing point shall be provided to facilitate commissioning of the installation. The mode of operation shall be adjustable.

4.36.7 Step control function shall be achieved by means of an electronic on/off controller. The controller shall provide for either switching of stages with decreasing valve or switching of stages with increasing valve or sequencing of stages with different modes of operation. The unit shall incorporate an adjustable switching time delay and shall provide for adjustable switching interval and differential on all stages. A plug-in service tester point shall be provided to facilitate commissioning of the installation.

4.36.8 Temperature and Humidity control shall be as indicated on the wiring Diagrams and/or specified in Part 5 of the Specifications.

4.36.9 All plants shall be controlled by means of a remote sensor mounted in the location indicated on the Drawings. When not shown, the sensor shall be located where it will respond to arrange temperature on humidity in the room.

4.36.10 All air conditioning and central ventilation plants as well as plants indicated on the Drawing as being controlled shall be switched on and off automatically by means of a programmable time switch.

Unless otherwise specified, the time switch shall have the following functions;

Day of week display

Time display

Auto/Off switch

Keyswitch to prevent programme alteration by unauthorised persons

Key pad for programming

Plus one hour override

Battery reserve of 24 hours minimum to maintain memory

4.36.11 The time switch shall generally be installed remote from the central plant and as such will act as a manual override switch. A manual override switch shall also be provided at the plant.

4.36.12 Thermostats and humidistats generally shall be mounted 1,8m above the floor unless otherwise indicated on the Drawings, and shall not be mounted on outside walls or partitions between offices if other locations are possible. Thermostats mounted on outside walls shall be provided with insulating bases.

4.36.13 Room thermostats and room humidistats in which the adjusting mechanism is integral with the sensing element shall have locked or concealed adjusting devices by means of which the operating points can be adjusted through a range of not less than 5 degrees and 10 per cent, respectively, above and below the operating points specified.

4.36.14 Electric temperature control systems operating at less than the normal, lighting circuit voltage shall be provided with transformers to supply power for equipment.

4.36.15 Transformers and line voltage controllers serving individual ventilating or air conditioning units may be fed from the fan motor leads, and other transformers and controls fed from the nearest distribution panelboard or motor control centre, utilising circuits provided for the purpose and not spare circuits or circuit provided for other purposes. Individual room controls and zone controls may be connected to any convenient outlet circuit providing power consumption does not exceed 3000 watts.

4.36.16 Transformers other than transformers in bridge circuits shall have primaries wound for the current available and secondaries wound for the correct control circuit voltage. Each transformer shall have capacity to operate simultaneously all apparatus connected to it and shall be capable of carrying a 25 per cent overload for one hour. No control transformers shall be rated less than 200 VA. Each transformer shall be enclosed in a steel cabinet with conduit connections and shall have a fused disconnect switch on the primary side, and a fuse cut-out or thermal cut-out on the secondary side.

4.36.17 All three phase equipment shall have phase failure, phase rotation and low voltage protection with automatic reset adjustable to a maximum period of 10 minutes.

4.36.18 Duct thermostats used for temperature control shall be remote sensing element type with controller mounted on a panel. Sensing elements (remote bulb averaging type or rigid stem) shall be located where they will respond to a representative temperature within the duct or casing. Operating and adjusting thermostatic mechanisms shall be enclosed in metal or phenolic resin cases and shall be installed outside of ducts and casings. Where ducts or casings are insulated, thermostats shall be mounted flush outside of insulation in such a manner that moisture will not condense on thermostat or on supports.

4.36.19 Where the distance from a bulb to a sensing element panel exceeds manufacturer's maximum recommended capillary length, a remote transmitter, mounted on the outside of the duct, shall be used between the elements and the operating and adjusting mechanism on the panel. Capillary tubes or wires other than stainless steel elements and operating mechanisms shall be protected by conduit moulding or flexible armour. Excess capillary lengths shall be neatly coiled and fastened out of the way. Capillaries and wiring shall pierce thermal insulation at the smallest practicable number of points and shall be properly sealed wherever they pierce an insulation vapour seal.

4.36.20 Pipe and Tank Thermostats shall be of the immersion type with liquid filled separable sockets. Where the socket is located more than 1,5 metres above the floor or where the operating and adjusting mechanism is specified to be panel mounted, the thermostat shall be of the remote sensing element type with liquid filled separable socket and the mechanism shall be mounted on a wall or column 1,5 metres above the floor or panel mounted. Where the distance from the bulb to a panel exceeds the manufacturer's recommended capillary length, a remote transmitter shall be used as specified for duct thermostats. Separable sockets shall be of brass or stainless steel heavy enough to withstand pulsations and turbulence in the fluid controlled. Protection of capillary tubing and wires shall be as specified for duct thermostats.

4.36.21 Fire safety thermostats of the rigid tailstock type shall be mounted in the return air stream to each unit or behind the common return air opening to the plant room as applicable and as indicated on the Drawings, to sense the return air temperature and shut down the entire system should the return air temperature exceed 40ºC. These thermostats shall be of the manual reset type.

4.36.22 Plants shall be started in sequence by means of time delay relays. The timing between switching stages shall be set at not less than 15 seconds.

4.36.23 Where applicable, the temperature control circuit of each water-cooled unit shall be interlocked with a water flow switch in the condenser water line so that the compressors will not operate unless the flow switch contacts are closed.

4.36.24 Heaters shall be interlocked with an air pressure differential switch mounted on the discharge duct of the respective unit to sense the air flow within the supply air duct in which the heaters are installed. Sail-switches will not be acceptable.

4.36.25 Heater circuits shall also be interconnected through a fire safety thermostat, with manual reset feature, to break the circuit should the temperature of the air in the duct exceed 55ºC. These safety thermostats shall also be of the rigid tailstock type and shall be mounted on the side of the ducts downstream of the heater batteries between 300mm and 600mm from the heating elements.

4.36.26 Where applicable for water-cooled systems, condenser water temperature shall be automatically controlled at the cooling tower as refrigeration will be required to operate on a year-round basis.

4.36.27 A remote sensor type proportional temperature controller with its sensing element suitably located to measure the temperature of condenser water flow shall be provided. This instrument shall control a damper actuator fitted to a damper in the cooling tower fan discharge, and shall cause variation of the air volume handled by the tower fan in response to condenser water temperature. A limit switch attached to the damper motor shall shut down the fan when the damper reaches the fully closed position and start when the damper reaches the fully open position.

4.36.28 Each refrigerant circuit within packaged air conditioning units shall include a dual pressure switch with manual reset on the high pressure side and an oil pressure switch, with manual reset feature, to stop the compressor if the oil pressure drops below a preset minimum, all as previously specified herein.

4.36.29 Ventilation and exhaust fans shall be interlocked with the air conditioning plant or as called for on the relative Wiring Diagram or indicated on the Drawings.

4.36.30 Fresh air intake fans shall be interlocked to operate only when the plant is switched on.

4.36.31 Static pressure controller shall be electronic remote sensing differential pressure detector mounted in the position indicated on the Drawings and arranged to sent a remote signal to a universal proportional controller which shall operate a motorised damper. The controller shall give a digital reading of the static pressure within the duct.

4.36.32 Pressure controller on chilled water shall be electronic remote sensing pressure detector mounted in the position indicated on the Drawings and arranged to transmit a signal to a universal proportional controller which shall operate a control device as required and indicated on the Drawings. The controller shall give a digital reading of the pressure within the system.

4.36.33 Sump pumps shall operate automatically under the control of their float switches. A single pole double throw selector switch contained in the relevant switchpanel shall allow manual selection of which pump can operate and which would be on standby. A high level alarm float switch shall initiate a warning light and bell at the switchpanel and bring the standby pump into operation.

4.36.34 **Building Automation System (BACS) Specification**

4.36.34.1 General

The Building Automation System (BACS) supplier shall furnish and install a fully integrated building automation system, incorporating direct digital control (DDC) for energy management, equipment monitoring and control, suitable for the building usage.

The control strategies shall be developed to ensure that the specified environmental conditions are maintained, whilst giving due regard to minimising of energy consumption in accordance with Building Regulations Part L2, and any subsequent revisions.

Materials and equipment installed shall be the catalogued products of the approved supplier and shall be the manufacturer's latest standard design that complies with the specification requirements.

The installer of the building automation system shall provide documentation supporting the

manufacturer's compliance with ISO-9002 (Model for Quality Assurance in Production, Installation and Servicing). The intent of this specification requirement is to ensure that the products from the manufacturer are delivered through a Quality System and Framework that will assure consistency in the products delivered for this project.

All peripheral equipment e.g. sensors, pressure switches, control valves and actuators, shall be of the same manufacture as the direct digital control modules and outstations.

The design of the BACS network shall be such that additional outstations may be added to the network in the future or the network expanded with minimal disruption to the normal operation of the system. Each local area network LAN shall have a minimum of 20% spare capacity to install additional devices.

The system design shall utilise the latest technology in "open" network architecture, distributive intelligence and processing, and direct digital control.

The automation level main plant DDC controls to be freely programmable based on DMAP programming language.

The products used in constructing the BACS management and automation level shall conform to the BACnet protocol on a LONtalk data communications network, for building automation and control networks. All products types shall have attained a BACnet Testing Laboratories (BTL) listing and display the BTL logo

Room units shall utilize a two-wire communication link at each controller with the capability for acquisition of room temperature, local set point, integral temperature indication and digital set point display, as specified by the control application.

The overall system-operating concept must be structured such that the data can be accessed at any point in the network(s) commensurate on the operator's access authority (security key/passwords).

It shall be possible, with additional hardware if necessary, to interrogate the system remotely via the following possible methods

- Telephone connection
- Building IT network
- Web browser technology with password access via IT networks
- Alarm reporting to mobile pagers/phones/e-mail etc
- Energy usage monitoring and control via Desigo Insight Building Management Systems.

4.36.34.2 Drawings and Records

Submit drawings for all equipment to be provided, including but not limited to:

.1 Software packages
.2 Management station central equipment
.3 Schematic diagrams showing system configuration and interconnection of management stations and all field panels.
.4 Descriptive data of all operating, user and application software including complete operators manuals, and programme manuals.

Final as-built documentation including the above items shall be included in the operation and

maintenance manuals.

Provide final documentation to serve the diverse needs of personnel concerned with instruction, operation, procurement, installation and maintenance.

Drawings and final documentation will be reviewed to ensure that such documents are in keeping with the intent of this specification and fully meet the requirements in terms of content and format.

Delivery of the final approved documentation, in hardcover 2-ring or 4-ring binders with index page and index tabs, is required before the Certificate of Substantial Completion will be issued.

Maintain a complete and current copy of all reviewed drawings at the job site.

All Licence rights to the control systems manufacturer's software packages shall be transferred to the client at the time of hand over. User Registration must be made on behalf of the client, direct to the control system manufacturer by the specialist System House Partner.

Three copies of all of the control system manufacturers Monitoring or BACS software shall be provided on CD-ROM, or other mass storage device, together with copies of any graphics and databases that may be required to re-install the system after a fatal computer failure.

4.36.34.3 Reference Standards

Provide electrical material and installation in accordance with the appropriate requirements, and in accordance with applicable sections of the current edition of the applicable local codes for electrical work and signalling systems. Install wiring in conduit or approved totally enclosed raceways. Do not use cable raceways or troughs. Approved ceiling plenum cable is acceptable where permitted by the local Authorities.

Provide electrical and electronic equipment which meets the CE conformity requirements as defined in CE directive 89/336/EEC Low voltage directive 73/23/EEC.

Provide BACS system which supports ANSI/ASHRAE BACnet Standard 135.

Automation level freely programmable DDC controllers shall have attained BACnet Laboratories (BTL) listing and shall display BTL logo.

The configuration of the Building Management System shall provide an "open" network architecture conforming to the ASHRAE's BACnet/IP protocol standard CEN ISO 16484-5.

The field level terminal unit controls shall conform to the ANSI/EIA Standard 709.1, employing the LonTalk protocol, and the product interoperability standards defined by the LonMark® Association.

Modem interfacing provisions shall meet EIA RS232C. Modems shall comply with the local required communication protocol with minimum transmission rate of 28,800 baud.

All equipment and systems installed under this Contract shall meet following specifications on electromagnetic compatibility:

Interference immunity according to EN50082-2
Emitted interference according to EN50081-1

Provide equipment which functions and meets all detailed performance criteria when operating in the following minimum ambient condition ranges:

Operating Temperature - 0 to 50 deg C [32 to 122 deg F] (Class 3K5 to IEC 721)
Relative Humidity 10% to 85% non –condensing (Class 3K5 to IEC 721)

The limits above, are minimums and shall not take precedence over ranges detailed in this or the

manufacturers specification.

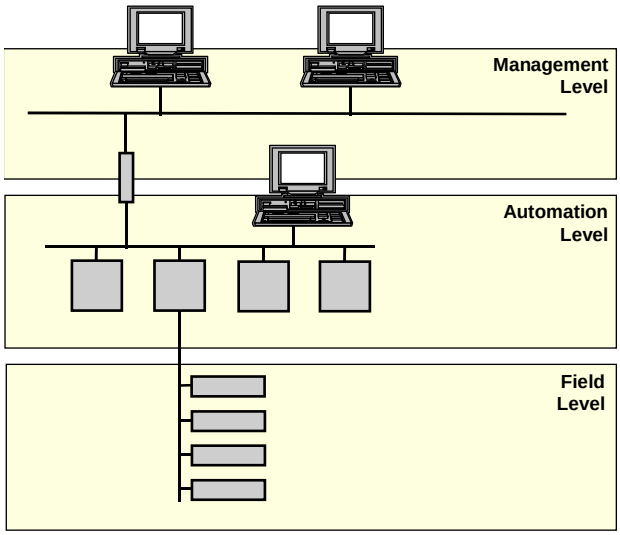
4.36.34.4 General System Architecture

The system shall be logically structured into distinctive levels based on the functions, performance, modularity and autonomy required at each level. Based on these requirements the most appropriate technology will be used. A physically flat architecture may only be appropriate to small systems.

Functionality shall be realised always on the most appropriate system level as defined below to ensure maximum resilience of the system

Each level shall be autonomous from the other. Applying three levels ensures the best performance, easier fault finding, better fault tolerance and expandability.

The levels are defined as Management Level, Automation Level and Field Level.



Peer to peer communication shall be possible on all system levels.

The system design shall be modular in structure to allow straight forward extensions.

4.36.34.5 Management level Functionality

Personal computer based operator management stations shall be provided for plant supervision and operation, alarm management, information and database management function. All real-time control functions shall be resident in the DDC controllers to facilitate greater fault tolerance and reliability.

The operator management station should be capable of multi-tasking 32-bit programs by utilising a Microsoft Windows 2000 or XP operating system.

The management station shall be capable of the following:

1 Display of graphical representations of the plant overlaid with live data
2 Monitor and operate / influence process devices
3 Receiving of alarm messages from the process level and directing them to the appropriate reporting device e.g. printer, pager, fax, e-mail
4 Monitor process devices for communication problems and other device faults.
5 Adjusting time strategies in the process level.
6 Long term storage of logged data from the process devices

7 Archiving / retrieve data to/from long term data storage
8 Display graphically the logged data
9 Custom application programming

The management station shall allow supplier independent integration of further subsystems.

The management station can either be stand alone or connected together via an IT network.

When management stations are connected together they must be capable of sharing data. Either one management station should become a network server or a dedicated server should be used.

For maximum fault tolerance, the management stations connect to the process level via point to point communications. This shall be via RS232, Ethernet/TCP/IP LAN / WAN or via AutoDial links.

The user interface shall be based on a basic taskbar, which is always visible, and which provides at all times a summary of the most important system information and essential system functions which are:

.1 Alarm summary which indicates for at least 3 priority groups the number of active alarms and system message status, site connection status and time and date .
.2 Control of access privileges and security mechanisms for access to program modules and third-party software at log-in and log-out.
3 User- and password-dependent access to systems and sub-systems.
.4 Automatic user-specific start sequences
.5 Facility to establish and terminate connection to various sites
.6 Simultaneous connection of at least of 4 sites via serial connections / 50 sites via LAN/WAN connections for a comprehensive overview on geographically distributed projects

Provide functionality such that any of the following may be performed simultaneously on-line, and in any combination, via user-sized windows. Operator shall be able to send information between applications reducing the number of operation steps.

System access control for individual access to sites, applications, functions and objects

Dynamic colour graphics and graphic control

Plant operation with explorer – all objects shall be displayed in a graphical tree structure in order to access points which are not included / defined in the graphics

Alarm handling – all the alarms shall be displayed in a graphical tree structure in order located alarms quick and easily.

Alarm routing to printers, pager, cellular phones/SMS, fax, e-mail on designated locations

Trend data module, including dynamic trend data definition and graphical presentation

History logging for alarms, user actions, system events and messages

Scheduling for operation and programming of the time programmes

Remote communications software, supporting remote access from/to process devices on automation via:
.1 AutoDial links (both dial-up and dial-down)
.2 ISDN facilities
.3 Ethernet / TCP/IP Local Area Networks
.4 TCP/IP Wide Area Networks

4.36.34.6 Management level network

The management level network shall use the standard BACnet protocol and shall be able to deal with the high data traffic with complex data structures between management stations and between the management station and the process level.

The network technology must be based the IT standards Ethernet and TCP/IP, and be compatible with the latest LAN, WAN technology.

When connected to an IT network this can be either a dedicated IT network for the building management stations or own the clients IT network.

When connected to a clients IT network, the management stations and process devices connected to that network have to co-exist with the other network devices.

Where the system works over more than one building over a large area (WAN - Wide Area Network), the client will be responsible for Data management devices ensuring the BACS can send information over routers, fire walls etc.

4.36.34.7 Automation level

Functionality

The Process devices control and monitor main plant equipment within a building. Each DDC controller shall have the ability to perform all the following routines.

.1 Process control & interlock functions.
.2 Generate alarms/events based on comparing measured values against know parameters.
.3 Time control strategies
.4 Runtime totalisation
.5 Trend logging of specific data-points with transmission of the logged values to the management level
.6 Energy calculations
.7 Backup of the data/program

The process devices shall be able to operate autonomously and independently from the management level.

The DDC control modules to be selected from either modular or compact type of device to suit the most economic inclusion of all data points specified.

The input/output connection to Modular controllers shall be via individual plug-in modules suitable for the particular peripheral device. The digital modules shall have visual indication of the status of the input/output. Digital input modules shall be capable of accepting control voltages up to 230vac and will have integral status indication.

Software application tool to utilize freely programmable DMAP software programming language.

In the event of a sensor failure an alarm shall be raised and the software application default to a safe value.

DDC Control Module Specification

Based on ANSI/ASHRAE standard 135-2001 (BACNet), ENV13321-1
Operation standalone or as part of LonTalk (clause 11) system network TP/FT-10, 78kBits with Built in BACnet/Lontalk interface
Optional connection to operator terminal, management station and via Web browser with Web server device.

Freely Programmable
Flash ROM, real time processing and multi tasking
32 bit dual processor system, 1.5 MB program memory
Supply voltage AC 24V +/-20% 50/60 Hz
Event driven data transmission
Automatic mains recovery
PPS2 connection for up to five two wire QAX room units
Digital output to be 250V 2A rated changeover contacts
Historical data memory storage
Software application stored in non volatile memory
Battery back up
Automation level network

All controllers and other devices shall communicate using the standard BACnet protocol.

The communications shall be able to transfer control parameters between devices at high speed and transmit logged data to management stations. The communications shall use change of state based communications to allow high event transmission speed on all transport media including AutoDial links.

This network shall be independent of the management network because IT networks require shutdown due to maintenance and because the network traffic could affect the performance of the IT network and vice versa.

The communications must be able to deal at least with following basic BACS functions:

.1 Change parameter
.2 Read parameter
.3 Share value with another process device
.4 Transmit alarm/event
.5 Transmit current logged data
.6 Time strategies, including optimum start and stop

Local Operator Terminals

A local operator terminal shall allow full operation of all DDC control modules connected to the LonTalk BACnet network. Functions to include

.1 Alarm monitoring with acknowledgement and visual and audible alarm indication.
.2 Pop up window with detailed message for alarms and events
.3 Alarm and event history
.4 Data point display and operation of all measured values, setpoints, plant states, operating states and parameters
.5 Graphic based display and operation of all time schedules, exception calendar, online trending and heating curve.
.6 User specific configurable overview of main values in plant
7 Multi user level access protection

The operator terminal shall have a high resolution 6 line illuminated display for graphics and text, keys for operation and a visual and audible common alarm indication. The textual information displayed must reflect the layout of building and plant with clear English descriptions of up to 40 characters.

The operators terminal shall be capable of being located either at any outstation or remote, powered by a local transformer. It shall be capable of being mounted in control panel door, backplate mounted, wall mounted or portable.

Each MCC enclosure shall be provided with local operators terminal mounted on the control panel facia.

Additional local operator terminals shall be able to be added to each control system, if required by the client, all of which shall be able to address any function on any control module. The additional operator terminal shall automatically read data from the network without the need for any pre configuration of the device.

Access all DDC Controllers on the network

Embedded Web Server

The system shall have the facility for a Web server to be added to allow full operation of all automation station control modules connected to the LonTalk BACnet network via a standard thin client/web browser. Functions to include

.1 Display of graphical representations of the plant overlaid with live data
.2 Data point display and operation of all measured values, setpoints, plant states, operating states and parameters
.3 Alarm monitoring with acknowledgement and visual and audible alarm indication.
.4 Alarm and event history
.5 Alarm transmission via SMS and e-mail
.6 Operation of all time schedules, exception calendar and heating curves.
.7 Reading of trend data with facility to export data to Microsoft Excel.
.8 Multi user level access protection
.9 Ethernet or Modem connection

All information accessed via the web browser shall be stored in web server device connected to the LonTalk BACnet network to allow access from any PC workstation with suitable Ethernet/IP network or modem connection. No installation of any custom software shall be required on the operators PC workstation.

BACS Web Server software shall support browsers used by Personal Digital Assistants like Siemens, 3Com, Palm Pilots and other Internet appliances.

Field level
Terminal Unit Controllers
All the terminal unit controllers shall fullfil following general requirements:
LONMARK communication
AC230 V power supply
mountable with screws or DIN rail
optional terminal cover for local installation without cabinet
Downloadable application software /adjustable parameter set, The type of use shall be defined by downloadable pre-tested application software.

The Terminal Unit controls on field level shall be capable of:

.1 Process control & interlock functions.
.2 Autonomous operation.
.3 local operating units

Common functions like grouping, scheduling, etc., shall be realised within a master controller on automation level. Each master controller shall have the ability to perform any of all the following routines:

.1 Process control & interlock functions
.2 Generate alarms/events based
.3 Time control strategies
.4 Runtime totalisation

.5 Trend logging of specific data-points with transmission of the logged values to the management level
.6 Energy calculations
.7 Backup of the data/program
.8 Energy calculations
.9 Backup of data/program

Room Units (for local operation)

All the room units shall fulfil the following general requirements:

Ergonomically designed plastic housing
Suitable for wall mounting or mounting flush over standard wall box, cable entry surface or flush;
Include mounting plate and accessories
Two-wire connection to the controller
Standard RJ45 socket for connection of a commissioning and room temperature;
Selection of automatic or manual fan speed control

All terminal unit controllers supplied on the project shall have the facility for local setpoint adjustment via a room unit.

It shall be possible to group the controllers as required (according to building zone or user), these groups being capable of communication over the LON bus.

For each 2-wire bus cable, all controllers connected to the LonTalk data bus must be capable of being operated remotely via service terminals at each controller or room operation unit.

Upward-compatibility with other hierarchical levels, such as operating, management and remote management systems (with the BACnet protocol in addition to manufacturer-specific protocols) is an essential and compulsory requirement.

Terminal Unit Controllers Basic functionality

The controllers shall fulfil the following real-time functions as a minimum:

Control and interlock for specific comfort conditions in rooms and self-contained zones

Provision of optimum comfort for the user while consuming the minimum of energy

The operation of all room functions in accordance with individual requirements, also via LONMARK protocol on the LON bus

Local operation using room operating units with individual adjustment facilities using 2 wire bus.

Remote operation and/or display via LONMARK on the LON bus

Room occupancy determined manually via the room unit or automatically via occupancy sensor

Detection of influencing variables, e.g. via window switches (energy hold-off)

Control of the room temperature in heating and/or cooling mode, and of the air volume (comfort mode)

Room temperature increased or reduced in unoccupied rooms (Stand-by mode)
Individual setpoint resets

Individual allocation of time programmes

Ability to communicate with other controllers, and with higher-level systems for programming and operation, including management stations for purposes such as the use of energy management functions

Integration of all room functions where required, including the facility to combine HVAC control with the control of lighting and blinds

4.36.34.8 Engineering

The possible uses of the controllers shall be defined in the form of pre-programmed standard HVAC applications which can be downloaded from an application library with a software tool. Following pre-tested standard applications shall be at least available:

Fan coil systems:

Electric heating coil
2-pipe system with change-over
2-pipe system with change-over and electric reheater
4-pipe system
4-pipe system with supply air temperature limitation
2-pipe system with change-over and outside air damper
4-pipe system with outside air damper
2-pipe system (cooling) and radiator
4-pipe system with air-side control

Common functions of above fan coil applications:
Window contact, occupancy detector, 3 operating modes
Manual fan control with room unit
Automatic fan control (single-speed or three-speed)
Options with 2-pipe systems: heating only, cooling only or change-over, via LON bus

VAV systems:

Single duct supply or extract air system
Single-duct supply air system with reheater/cooler
Single-duct supply air system with electric reheater
Dual duct supply and extract air system
Dual duct supply and extract air system with reheater/cooler
Dual duct supply and extract air system, with electric reheater

Common functions of above VAV applications:
Window contact, occupancy detector, 3 operating modes
Built-in pressure sensor
DC 0 ... 10 V inputs for external pressure sensors
Control of compact volume controllers
Direct control of damper actuators

Integrated room management applications:

The combined applications shall consist of a HVAC application:
Fan coil
Heated / chilled ceilings and radiators
VAV systems
With one ore more of following electrical functions:
Groups of lights on/off
Groups of lights dimmed
Blinds up/down (with or without slat adjustment as required)

4.36.34.9 Field Level Network

All controllers and other devices shall communicate using the standard LonMark protocol on the LON bus. Network variables, data structures and mechanisms involved shall correspond to the >Integrated Room Management< template supplied by LNO in LonMark.The individual room management system must ensure demand-based control of individual thermal comfort, while at the same timekeeping energy demand to a minimum.

Integration into a common communications network must be achieved peer-to-peer and with the next higher hierarchical level via the LON bus interface and LonMark protocol.

Use of communication standards

Only the following standards are appropriate to be used at the three levels.

.1 Management level- BACnet, Ethernet TCP/IP
.2 Automation level- BACnet on Lon
.3 Field level- LonTalk with LonMark profiles

Where a configuration software tool is used to set-up the network and devices from a number of manufactures to be connected to the same network, only one tool from one manufacturer shall be used to configure the whole project to ensure consistence and interoperability.

If the standard creates a project specific database in order to configure network, the client shall have ownership of that database.

Integration of secondary systems

Integration's shall be carried out at the most appropriate level within a system, depending on the functions and interaction required. The following integrations must be possible.

LonWorks
LonMark
BACNet /LonWorks
BACNet/IP
OPC

Integration of standard proprietary buses :Modbus, M Bus, KNX

As part of the requirements for an open system devices with a Native BACnet protocol shall be connected onto a common field bus backbone network directly without any Gateway/Protocol converter device.

If interaction is required between different sub-systems, the integration shall be carried out at either the automation or field level. The integration must not occur at the management level.

Link to a third party software package such as a Planned Preventive Maintenance package or a Energy Monitoring package shall be carried out at the management level.

When sharing alarm and historical information with Maintenance Management and Energy Management packages, the management system shall provide the information in a standard commercially available format e.g. MS Access and using standard mechanisms e.g. ODBC .

Real-time "live" information shall be transferred form the management system to a third party package e.g. MS Excel, either by a standard inter-application mechanism e.g. DDE or OPC or by developing a connection by using a documented API for the management system.

Where a physical connection is required between a 3rd party device and the management system, the sub-system supplier shall provide the necessary line drivers and cables, documentation and support to make the connection into the device that will provide the protocol conversion.

4.37 SWITCHPANELS AND CONTROL BOARDS

4.37.1 Provide and install, in the positions indicated on the Drawings, switchpanel and control boards complying in operating principals with the automatic control sequences as described before and the relevant control and wiring Diagrams.

4.37.2 The Schematic Control Diagrams serve to illustrate the mode and sequence of operation and the required protection interlocking, and circuits may be modified to accept individual suppliers electrical components selected by in so doing no inherent protection or mode of working shall be adversely affected.

4.37.3 The Subcontractor shall be responsible for the checking and modifying if necessary, of all wiring Diagrams prepared by the Engineer for the guidance of the Subcontractor and any errors shall be brought to the attention of the Engineer before work is started on the equipment or installation.

4.37.4 Before commencing with the manufacture and wiring of the switchpanel and control boards the Subcontractor shall submit three copies of up-to-date wiring Diagrams, schematic ladder type Diagrams of the control systems and dimensioned panel layout Drawings to the Engineer for approval. All Drawings shall show the correct terminal numbers and wire identification numbers to be used.

4.37.5 The Engineer shall be informed of all modifications to the wiring made until the end of the guarantee period and updated Drawings shall be submitted immediately after each modification is made.

4.37.6 The complete electrical installation and all electrical equipment and materials covered under this Subcontract shall comply with the latest edition of the S.A.B.S. Specification. The workmanship and installation shall comply with the "Standard Regulations for the Wiring of Premises".

4.37.7 All components of a similar nature shall be of one make with corresponding parts being interchangeable. All equipment shall be of robust construction and have ample ratings for the duties imposed.

4.37.8 System Fault Levels for which the switchpanel components shall be designed and selected shall be at least as specified in Section 5 or indicated on the Drawings. It shall be the responsibility of the Subcontractor to ascertain the correct fault level from the Engineer which shall n not less than 5 kA.

4.37.9 All equipment in the switchpanel such as fused switches and moulded case circuit breakers, controlling outgoing circuits, shall be rated accordingly. Where moulded case circuit breakers are not capable of dealing with this fault level, they shall be backed up by HRC fuses which must be capable of being replaced without any other circuit being switched off to do so, and must be capable of being made "dead" for replacement.

4.37.10 Switchpanel and control boards shall be of the floor mounted type for panels having a total face area in excess of 1,2m², and wall mounted if less than 1,2m². Where switchpanel exceed 1,2 metres in length they shall be divided into multi-sections.

4.37.11 All switchpanel, unless otherwise specified, shall be arranged for front access only and top cable entry with the main incoming isolators positioned on the extreme left hand side of each switchpanel. The switchpanel shall be arranged for top exit via cable ducts.

4.37.12 All switchpanel shall be adequately ventilated either by natural or forced ventilation.

4.37.13 When starting equipment creates higher than normal ambient temperatures the switchpanel shall be adequately ventilated by means of splash-proof top ventilating openings provided with vermin proof screens.

4.37.14 The switchpanel and control centres shall be the products of specialist manufacturers of this class of equipment, as approved by the Engineer, and shall be purpose made to contain all switchgear, controls, instruments and indicating equipment, and shall be complete with all internal wiring, all conforming with the following requirements.

4.37.15 Switchpanel and control centre casings shall be fabricated from 2,0mm thick mild steel suitably stiffened with mild steel sections and fitted with removable hinged doors, with flush-mounted locks each provided with triplicate keys, as well as removable panels secured with chromium plated dome nuts.

4.37.16 Wall mounting panels shall be of the surface type with removable inner mounting chassis.

4.37.17 Floor standing switchpanel and control centres shall be mounted on channel section mild steel bases.

4.37.18 Door widths shall not exceed 900mm for all switchpanel and all doors, removable covers, door pillars, mullions, etc., shall be dust resistant and provided with oil resistant, closed-cell composition, synthetic rubber or similar gaskets. Gasketed surfaces shall be so constructed that gasketing material is retained by metal channels and does not depend entirely on an adhesive holding the gasket on a flat metal surface.

4.37.18.1 All fixing screws shall enter holes tapped into an adequate thickness of metal or nuts welded to the back surface of the metal plates. Self-tapping screws will not be acceptable.

4.37.19 The switchpanel shall be so designed that, with the doors open, no switchgear is exposed, this being concealed behind removable recessed 1,6mm thick cover plates neatly slotted to allow protrusion of circuit breaker toggles only. All switches, the main circuit breakers, on/off handles, instruments and indicating equipment, reset buttons and pilot lamps only shall however be fully exposed and operable, as relevant, without the need to open the doors to the switchpanel, this equipment being flush mounted on suitable panelled sections of the switchpanel on one side of or above the access doors.

4.37.20 Adequate barriers shall be provided in the switchpanel and control boards to segregate each load circuit compartment from all others, and from the busbar chamber, in such a way that transmission of flame from one compartment to another is minimized.

4.37.21 Each cubicle shall be self-contained and hold only the equipment for one circuit. It shall be capable of being isolated and the equipment worked on without interfering with other equipment. Ample access and space shall be allowed for inspection, repair and replacement of equipment and component parts.

4.37.22 The electrical equipment within the panels shall be mounted on steel chassis located behind the coverplates previously referred to. Such chassis shall also be used for the mounting of the relevant busbars.

4.37.23 The finish of the panels shall be epoxy powder coated or baked enamel. The boards shall be given three coats of paint after an initial coating of zinc-rich primer to give a high-class gloss finish.

4.37.24 Busbars shall be provided in hard drawn annealed copper loaded to not more than 1,55 Amps/mm^2 of copper on a 50^{o}C rise and shall be enclosed in a top horizontal and accessible compartment with steel casing separating the busbars from other equipment. Busbars shall be mounted on porcelain or epoxy resin type busbar insulators mechanically braced to withstand 40 000 Amps through fault current. The clearance between busbars shall not be less than 40mm between phases and 25mm to earth, and they shall be secured by bolts having a diameter of not less than the thickness of the busbars with a minimum diameter of 8mm.

4.37.25 Machined bolts and nuts with washers and spring washers shall be used and busbar supports shall have a maximum pitch of 900mm. Connections shall be made by means of copper, preferably double indent, compression lugs. All busbar joints shall be silver or tin plated and connected with high tensile steel cadmium plated bolts and lock washers. Busbars shall be taped up after all connections are made

4.37.26 Neutral bars are to be not less than half the cross-sectional area of phase busbars, but not less than 25mm x 6mm, and are to be mounted on porcelain or epoxy resin type insulators, where heaters or other phase to neutral loads are used.

4.37.27 Where neutral bars are purely on the control side, 15mm square brass bars with 2 tapped holes per way may be used, mounted on bakelite or equal insulators.

4.37.28 Earthing strips of not less than 25mm x 6mm copper shall run full length of the complete floor standing panels, either at the top or bottom of the panels where it must be securely bolted to the switchpanel framework to ensure good continuity.

4.37.29 Wall mounted switchpanel shall be provided with an earthing brass bolt of not less than 10mm diameter, securely fixed to the panel chassis.

4.37.30 All wiring within the panels shall be neatly grouped in horizontal and vertically run approved fire resistant P.V.C. trunking with clip-on removable covers. All wiring shall also be colour-coded in the colours red, yellow and blue for the relevant phases and black for neutral, the busbars being similarly marked.

4.37.31 Power wiring shall be of 2,5mm² minimum section P.V.C. covered stranded wire rated for 600 volts.

4.37.32 Control wiring shall be minimum 1,5mm² P.V.C. covered, stranded, 250 volt grade wire with bared ends soldered.

4.37.33 All switchpanel shall be carefully designed and sized to ensure ample space for wiring and making-off incoming cables.

4.37.34 Fused switches shall be of the fault making, load breaking type selected for the continuous rating of not less than the full load rating of the equipment which they control.

4.37.35 All fused switches shall be of the 500 volt metal clad type with self-aligning switch contacts of the quick make and break type having two breaks in series per pole. Switch covers are to be hinged and mechanically interlocked so that the cover can be only opened with the switch in the "off" position. Cartridge fuse links shall be fitted on each live pole. The sizes of the fuses shall be determined by the load or starting characteristics of motors and the system fault level.

4.37.36 All fuses shall be of the HRC type with a minimum rupturing capacity to suit the system fault levels at 400 volts. Spare fuses of 25% of the total quantity with a minimum of three of each size and type, including control circuit fuses shall be provided.

4.37.37 Isolators shall be of the "on load" type and of ample rating for the maximum load applicable. Live side terminals on all isolators must be shrouded or otherwise insulated against inadvertent contact.

4.37.38 Isolators installed within the switchpanel shall be housed in separate enclosures, the door of which shall be interlocked with the switch operator to prevent the door from being opened unless the switch is in the open position and prevent closing of the disconnecting switch while the enclosing door is open unless a manual bypass is actuated, also to prevent closing of the disconnect switch until the door hardware is fully engaged. The stem operating the isolator shall not be less than 12mm in diameter and shall not be longer than 100mm. Provision shall be made available for padlocking the disconnect switch in the open position only with up to three 10mm shackle padlocks regardless of whether door is open or closed.

4.37.39 Air break circuit breakers shall be of the double break type, and shall have a continuous rating not less than the total full load rating of the equipment. They shall have a fault capacity suitable for the design level of the system. They shall have adjustable overloads, covering the operating range of the equipment served, which shall be series tripping up to 800 Amp and C.T. - operated above this value.

4.37.40 Moulded case air circuit breakers shall be rated to comply with the fault level and current rating specified to suit the load and shall be fitted with thermal overloads and instantaneous magnetic over-current releases.

4.37.41 The breaking capacity, in kilo-amps, shall be suitable for the prospective fault current expected in the circuit. Under-voltage shunt trips shall not be incorporated unless specifically called for.

4.37.42 Miniature circuit breakers shall be to S.A.B.S. 156/1963. All parts of the mechanism shall be of corrosion resisting material or suitable protected by plating or other approved means to prevent corrosion from normal atmospheric conditions. All circuit breakers shall, as far as possible, be of the same type and manufacture throughout the installation.

4.37.43 Current transformers shall be air insulated and shall have an accuracy within 2% of the 0-100% scale output.

4.37.44 Magnetic contractor shall not be smaller than N.E.M.A. size 1 or equivalent, with encapsulated operating coils rated at 220 Volt, 50Hz. Each starter is to be furnished with one spare N.O. (Normally Open) and one N.C. (Normally Closed) auxiliary contacts rated at 5 amperes. Each starter shall also have provisions for adding two additional sets of auxiliary contacts, either normally open or normally closed. Contacts and coils shall be replaceable without removing the entire contactor from the cubicle.

4.37.45 Motor Starters shall comply with BS775 and NEMA specifications and shall have two thermal overload relays which shall be of the bimetallic ambient temperature compensated, manual reset type. Overload relays shall be resettable at any time after tripping without rendering the relays inoperative. All terminals shall be shrouded and the contact mechanism shall be trip-free so that the non-teasable snap action contacts cannot be held closed against continued overload. The ultimate trip current of overload devices shall be a nominal 115% of the motor full load current. With special hard starting, e.g. axial flow fans, it may be necessary to increase the nominal value but in no case shall the overload ultimate trip current exceed 130% of the motor full load current.

4.37.46 Control relays shall be either of the heavy duty industrial type, 600 volt with minimum 10 ampere replaceable contacts and shall be equipped with 220 volt, 50 Hz holding coils for continuous operation within a voltage range of 200 to 260 volts. Holding coils shall be replaceable without removing the entire relay from the cubicle or;

4.37.47 Alternatively the control relays may be of the plug-in type, hermetically sealed in plastic containers.

4.37.48 Phase Reversal Relays shall contain contacts so that on failure or phase reversing the plants will stop. The relays shall be equal to Cutler-Hammer Igranic and shall be installed as indicated on the Wiring Diagrams.

4.37.49 Timers shall be of the synchronous drive type equal to SIEMENS or TESCH.

4.37.50 Rotary switches shall be gauged type, minimum rating 6 amperes at 220 volts single phase, have engraved plastic faceplates for usage designation and equal to Telux or Kraus & Naimer. Where called for they shall be key operated type, supplied with three sets of keys.

4.37.51 Sequence controllers to start plant with minimum of 15 seconds time delay between each start-up of motors of 5kW and over shall be provided to avoid heavy current inrush on plant start-up. Sequence controllers shall be synchronous motor driven type and shall automatically recycle to zero position after power interruption and on normal plant shutdown.

4.37.52 Pilot lights shall be of the low voltage incandescent, multi-lamp, push to test type, equal to SWISSTAC SERIES 2, with 18 x 24mm rectangular "plexiglass" face engraved to indicate the function as noted on the Wiring Diagrams. The colours of the face plates shall be as noted on the Wiring Diagrams to generally indicate the following:

Indication	- Amber
Operation	- Green
Failure or Alarm	- Red

4.37.53 Pilot lights shall be grouped in the sequence of operation of the plant components with amber coloured lamps generally above green lamps and the red "failure or alarm" lamps below the respective green "operation" lamps.

4.37.54 Reset Pushbuttons shall be similar in appearance and size to the pilot lights, equal to SWISSTAC SERIES 2, and shall be mounted adjacent to the Red Failure or Alarm pilot lamps on the switchpanel.

4.37.55 The main incoming switch of each switchpanel shall be fitted with three Ammeters and one Volt meter with selector switch.

4.37.56 Kilowatt-hour meters shall be fitted as specified on the Drawings. The meters shall have 6 digits and manual reset knob. Above 100 Amp the kWh-meter shall be fitted with current transformers.

4.37.57 Ammeters shall be fitted where specified or shown on the Drawings. Ammeters over 50 Amps shall be operated by current transformers of the ring type. Ammeter shall have an accuracy of 2% of the scale range or better. For non-inductive loads the scale of the Ammeters shall not exceed the maximum current drawn by more than 40%. Motor ammeters shall be suitable for the starting current of the motor, and shall have an expanded scale in the region of the operating current.

4.37.58 Volt Meters shall be of the moving iron or moving coil type.

4.37.59 All indicating instruments shall be of the flush mounted square faced pattern with 96mm dials.

4.37.60 Pressure and temperature reference instruments shall be anti-vibration mounted where they may be subject to vibration.

4.37.61 Compensating cables to be run separate from all other cabling.

4.37.62 Each power circuit shall be contained in its own, individually isolatable compartment, and shall be furnished with its own circuit breaker as shown on the Drawings.

4.37.63 Each control circuit shall be protected with a single pole miniature circuit breaker. Controls shall be suitable for 220 volt operation.

4.37.64 Terminal boards or blocks shall be mounted in each switchpanel for all external connections and shall be so located that they are readily accessible from the front of the switchpanel, and not in the wiring gutter leaving it completely free for power and control wiring. If terminal blocks are of the "split" disconnect type the female part shall be secured to the removable unit cubicle and the male part free and be of a closepin type. The disconnect type terminal blocks shall be held together with screws or clamps. Terminal strips shall be properly labelled and panel and field wiring shall be marked accordingly by means of numbered ferrules. Not more than one incoming and one outgoing wire shall be fixed to any one terminal.

4.37.65 Labels showing the unit designations shall be provided adjacent to each of the terminals.

4.37.66 The Switchpanel shall be fully labelled with engraved black ivorine labels having 6mm high white lettering. The labels shall be riveted to switchpanel cover or chassis plates to identify all switchgear, relays, instruments and controls, etc., on the face of or inside the switchpanel.

4.37.67 Equipment operating above 250 volts shall be fitted also with a red danger label.

4.37.68 Embossed Tape or Labels fixed with adhesive will not be acceptable.

4.37.69 The Subcontractor shall be responsible for marking all switchgear and other equipment on the wiring diagrams with the working of the labels to be used.

4.37.70 All cable terminals shall be clearly identified by permanent labels.

4.37.71 Every wire inside and outside the switchboard shall be fitted with ferrules and labelled with identical numbers at both ends.

4.37.72 All terminal numbers and wire identification numbers shall correspond with identical numbers which must be shown on the wiring and control diagrams.

4.37.73 Works tests may be witnessed at the discretion of the Engineer, who shall be given one month's prior notice in writing of the date on which they will take place. Three copies of wiring Diagrams and ladder type schematic Diagrams complete with terminal numbers shall be sent to the Engineers at least 14 days before testing can be commenced.

4.37.74 Testing shall be carried out on all complete equipment, including;

4.37.75 High voltage insulation and insulation resistance tests to earth and between phases.

4.37.76 Satisfactory operation of relays shall be proved.

4.37.77 Closing and opening operation of all starters and contactors shall be satisfactorily demonstrated.

4.37.78 All mechanical interlocks shall be satisfactorily demonstrated.

4.37.79 Satisfactory operation of pilot lights.

4.37.80 Satisfactory operation of current and voltage instruments.

4.37.81 Operation of all control circuits shall be proved by simulating operation of switching devices in the external circuit.

4.37.82 In addition, all components parts shall comply with the type tests specified in the S.A.B.S. or B.S. Standards.

4.37.83 The pre-delivery test is not a final acceptance test, and does not absolve the Subcontractor from his responsibility for the switchpanel.

4.37.84 All protective devices throughout shall be correctly set by the Subcontractor to the approval of the Engineer. Before any circuit is energised, the Subcontractor is required to obtain all the necessary data for correct settings to be established.

4.37.85 The Subcontractor shall be responsible for the complete electrical installation. Selection of equipment of appropriate rating and capacity, including the rupture capacity of fuses and circuit breakers, covered under this Subcontract.

4.37.85.1 Provide for each item of equipment located out of sight of the electrical switchpanel serving same, a remote lock-up stop housed in a dustproof case. Where located in positions exposed to the weather, they shall be waterproof type fitted with suitable watertight cable entry glands.

4.38 ELECTRICAL CABLING AND WIRING

4.38.1 General

4.38.1.1 Mains electricity supplies as relevant, will be provided by others, including making-off of cables within the electrical switchpanel provided by the air conditioning Subcontractor who shall attend upon and liaise with whoever brings power cabling to his switchpanel.

4.38.2 Cabling

4.38.2.1 Termination of P.V.C. insulated armoured cables

4.38.2.1.1 All cables shall be terminated with approved glands ensuring a watertight connection between the sheath, gland and equipment. In cases where copper earth conductors are joined to the armouring, special glands adhering to S.A.B.S. 150-1970, shall be used.

4.38.2.1.2 The glands to be used shall be constructed so that the armouring of the cable is clamped between two bevelled cores with a screw-clamp.

4.38.2.1.3 Glands shall be suitable for PVC SWA and PVC sheathed general purpose 600/1 000 volt cable.

4.38.2.1.4 The non-watertight glands shall be easily converted to watertight glands by means of sealing rings and waterproofing shroud. The glands shall be Pratley, Captive Cone or other approved type. The glands shall be fitted with an earth terminal.

4.38.2.1.5 On the cable entry side of the barrel, a groove shall be provided, to accommodate a rim of the waterproof shroud.

4.38.2.1.6 The shrouds shall be made of non-deteriorating neoprene or synthetic rubber, and shall be resistant to water, oil and sunlight. The shrouds shall fit tightly around the glands and cable.

4.38.2.1.7 Epoxy-resin jointing materials shall be "Scotch-Cast" Splicing Kits or approved alternative and shall be used strictly in accordance with the supplier's recommendations.

4.38.2.1.8 Copper cables shall be terminated either by crimped or soldered lugs. Termination of aluminium cables are to be made by a method approved by the Engineer.

4.38.2.1.9 The cable gland shall be screwed to the gland plate or equipment and fixed with a locknut.

4.38.2.1.10 A Neoprene or P.V.C. shroud shall be used to seal the gland and sheath watertight.

4.38.2.1.11 Cable cores shall be connected to equipment with suitable lugs.

4.38.2.1.12 Exposed armouring shall be covered with bitumen-base paint.

4.38.2.1.13 Cable ends shall be supplied with the necessary earth connection.

4.38.2.1.14 A P4000 "SANKEYSTRUT" channel or other approved means of support shall be provided to remove mechanical stress from the cable glands.

4.38.2.2 Connection of cable cores

4.38.2.2.1 Ferrules shall be used as far as possible where cable cores are connected directly to equipment with screws against the conductor strands. Alternatively cable ends shall be soldered.

4.38.2.2.2 Contact surfaces shall be cleaned properly where cable cores are bolted onto terminals. Suitable lugs shall be used.

4.38.2.2.3 Lugs may be crimped or soldered. For larger size cables purpose designed mechanical or pneumatic crimping tools shall be used.

4.38.2.2.4 Care shall be taken to leave no strands exposed when cutting away insulation from cable cores to fit into lugs.

4.38.2.2.5 The correct size of lugs shall be used for each size of conductor.

4.38.2.3 **Fixing of cables**

4.38.2.3.1 Cables may be installed in one of the following ways:

On horizontal cable trays,
Against vertical cable trays with suitable clamps,
Against horizontal or vertical metal supports or brackets with suitable clamps, or
On clamps which are fixed to the structure.

4.38.2.4 Clamps

4.38.2.4.1 Suitable clamps (cleats) which will secure cables without damage shall be used. Clamps shall consist of adjustable metal wings which clamp to a metal support, or consist of two halves that are bolted together. Wooden blocks shall only be used in exceptional circumstances with the approval of the Engineer. The correct clamps size to fit the cable shall be used. Cables of different sizes may only be fixed by a common clamp when the clamp is specially made to accommodate the various cables.

4.38.2.5 Distance between fixings.

4.38.2.5.1 The maximum spacing between cleats (clamps) to which the cables are fixed in horizontal and vertical cable routes shall be determined from the table below. Additional cleats shall be installed at each bend or offset in the cable run. The maximum distance between supports or cleats for multi-core cables shall be 20 times the outside diameter of the cable with a maximum spacing of 550mm for unarmoured cables and 30 times the outside diameter of the cable with a maximum spacing of 900mm for armoured cables.

4.38.2.6 Maximum spacing of support cleats (mm)

Cross-Sectional	Armoured Cables		Unarmoured Cables		Mineral Insulated Cables	
Area of Cable	Cable Routes		Cable Routes			
Conductors mm²	Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical
1,5	450	750	300	400	600	
2,5	450	750	300	400	600	
6,0	600	750	300	400	600	
10,0			750	900	400	450	900
16,0			750	1000	450	550	900
25,0			900	1000	450	550	1200
35,0			900	1000	450	550	1200
Larger than 35,0			900	1000	450	550	1200

4.38.3 **Wiring and Conduits**

4.38.3.1 **E**xcept in cases where cables are specified, all wiring shall be P.V.C. insulated, single core stranded copper conductors and bare stranded or green P.V.C. insulated copper conductors for earth continuity in compliance with S.A.B.S. 150 and the installation shall comply with S.A.B.S. code of practice for the wiring of premises S.A.B.S. 0142-1981 as amended.

4.38.3.2 The colour of the conductors for all 220V circuits shall correspond to the colour of the supply phase for that circuit. Neutral conductors shall be black. All other conductors in the board, supplying control circuits, etc. shall be coded in colours other that those specified above. A colour code shall be devised for each board and the colour code shall be shown on the wiring Diagrams. All conductors that terminate at terminal strips and all conductors used for the internal wiring of the switchboard, shall further be identified at both ends by means of durable cable marking ferrules. P.V.C. or other tape is not acceptable. The numbers of the markers shall also be shown on the wiring Diagrams.

4.38.3.3 Conduits shall be heavy gauge, welded or solid drawn to S.A.B.S. specifications. All joints shall be screwed. No conduit less than 200mm shall be used. Conduit fittings and boxes shall be of enamelled malleable iron.

4.38.3.4 Galvanised conduits and conduits fittings shall be installed in positions exposed to weather, or in moist surroundings. Where galvanising has been removed by threading, cutting, etc., the exposed parts shall be suitably treated or painted to render weatherproof, and rust resistant.

4.38.3.5 Conduit shall either by screwed and locknutted to, or locknutted on both sides, and bushed on the inside of the box or appliances in which it is terminated. Only solid brass bushes shall be used. Alternatively, and particularly in distribution boards, conduits shall be terminated with couplings and brass male bushes.

4.38.3.6 Conduit in roof spaces shall be run parallel and at right angles to roof members and shall be secured to these members by means of saddles and screws.

4.38.3.7 No conduit is to cross an expansion joint in the structure without an approved arrangement for crossover. Where details of crossover are not given, the Subcontractor shall refer to the Engineer for instructions.

4.38.3.8 The Subcontractor shall notify the Engineer in good time before any conduits in concrete are covered so that tubing may be inspected and checked before concrete is cast, and shall attend on the Engineer during such inspections.

4.38.3.9 Conduit for future requirements shall be terminated with boxes and overlapping coverplates, and fitted with galvanised steel draw-wires. Where such conduit terminations project from the wall or slab, they shall be fitted with couplings and plugs. Such terminations in exposed positions shall be sealed with bitumen and protected with weatherproofing paint.

4.38.3.10 Inspection facilities shall be provided at every third change of direction in a run of conduit and at maximum intervals of 10 meters on straight runs. The use of tees and elbows will only be allowed in exceptional cases and shall be inspection type.

4.38.3.11 Exposed conduits shall be fixed with steel saddles of same finish as conduit on centres not exceeding 2 meters.

4.38.3.12 Conduit boxes to be cast in concrete shall be secured to shuttering by means of 5mm screws and nuts, unless some other method of fixing is approved by the Engineer.

4.38.3.13 Drawboxes and blank boxes in R.C. slabs, beams, columns, or in walls shall be fitted with substantial oversized metal coverplates, fixed with countersunk screws, before surrounding surfaces are painted. Drawbox positions must be approved and care shall be taken that they do not affect the appearance of the building adversely. Where possible a single coverplate shall be fitted for a number of adjacent drawboxes.

4.38.3.14 Drawboxes in roof spaces which are only accessible above ceiling, shall not be installed in positions where clearance from ceiling to roof is less than 1 meter.

4.38.3.15 Blank switch and plug boxes shall be fitted with blank coverplates and screws to match those specified for switches and switch sockets.

4.38.3.16 Mounting heights of boxes shall be as indicated on the Drawings which shall refer to the distance between the centre of the outlet box and the finished floor level, unless otherwise specified or indicated. Where two similar outlets occur adjacent to each other, these shall line up accurately horizontally, unless otherwise indicated.

4.38.4 **Earthing**

4.38.4.1 All earthing shall be carried out in accordance with wiring regulations, earthing connections being executed with appropriate copper earthing strip using brass bolts, nuts and washers to ensure continuity to main building earth provided by others.

4.38.4.2 Each run of P.V.C./S.W.A. multi-core cable or mineral sheathed cable shall carry an additional conductor to be used for earth continuity and properly made-off for this purpose. On P.I.L.C.S.W.A. cable use a separate bare stranded copper earth continuity conductor with minimum section 1/2 of size of conductor inside cable.

4.38.5 **Cable Trays**

4.38.5.1 The Subcontractor shall supply and install all cable trays or ladders as specified or as required by the cable routes including the necessary supports, clamps, hangers, fixing materials, bends, angles, junctions, reducers, T-pieces etc.

4.38.5.2 For coastal areas CABRAC CABLE TRAYS or equal and approved shall be provided as supplied by B.R.C. Weldmesh (Pty) Limited, Telephone No. (011) 894-3246/9.

4.38.5.3 The cabrac shall be the medium duty type pre-galvanised epoxy coated.

4.38.6 **Cable Ladders**

4.38.6.1 **General**

4.38.6.1.1 Metal cable ladders shall consist of 76mm high side rail of 2mm minimum thickness. Cross pieces consisting of P3300 "SANKEYSTRUT" channel sections shall be spaced at maximum intervals of 250mm. Where cables of 10mm² or smaller are installed on cable ladders, the spacing of the cross pieces shall be 125mm. Cables shall be clamped in position by means of purposes made cable clamps that fit into the cross pieces. Cross pieces consisting of slotted metal rails which accommodate plastic or metal cable binding bands, may be used in vertical cable runs against walls etc. where the prior approval of the Engineer has been obtained. These cross pieces are not acceptable in horizontal cable runs.

4.38.6.2 Finishes

4.38.6.2.1 Metal cable ladders shall be finished as follows:

In coastal areas	hot-dipped galvanised to S.A.B.S. 763 or epoxy powder coating
False ceiling voids	electro-galvanised or epoxy powder coating
Vertical building ducts	hot-dipped galvanised to S.A.B.S. 763 or epoxy powder coating
Plant rooms, substations, service tunnels, basements	electro-galvanised or epoxy powder coating
Damp areas, exposed	hot-dipped galvanised to S.A.B.S. 763 or epoxy powder coating
Undercover industrial applications	hot-dipped galvanised to S.A.B.S. 763 or epoxy powder coating

4.38.6.2.2 The abovementioned finishes shall apply unless specified to the contrary in the Detailed Technical Specifications. Hot-dipped galvanised or electro-galvanised trays and ladders shall be cold galvanised at all joints, sections that have been cut and at places where the galvanising has been damaged. Powder coated trays and ladders shall likewise be touched up at joints, cuts and damaged portions using spray canisters recommended by the manufacturer of the trays and ladders.

4.38.6.3 Supports

4.38.6.3.1 Trays shall be supported at the following maximum intervals:

1,6mm thick metal trays	- 1m maximum spacing
Metal trays with folded over return and 50mm upstand	- 1,22mm spacing
2,4mm thick metal trays, and 75mm return	- 1,5m spacing
Metal cable ladders	- 1,5m spacing
3,0mm thick P.V.C. trays with 40mm return	- 1,0 maximum spacing
4,0mm thick P.V.C. trays with 60mm return	- 1,5m maximum spacing

4.38.6.3.2 In addition trays and ladders shall be supported at each bend, off-set and T-junction.

4.38.6.4 Joints

4.38.6.4.1 Joints shall be smooth without projections or rough edges that may damage the cables. The Subcontractor will be required to cover joints with rubber cement or other hardening rubberised or plastic compounds if in the opinion of the Engineer joints may damage cables. Joints shall as far as possible be arranged to fall on supports. Where joints do not coincide with supports, joints shall in the case of trays with single returns (items (a) and (c) of 4.15.8) be made by means of wrap-around splices of the same thickness as the tray and at least 450mm long.

4.38.6.4.2 The two cable tray ends shall butt tightly at the centre of the splice and the splice shall be bolted to each cable tray by means of at least 8 round head bolts, nuts and washers. Splices shall have the same finish as the rest of the tray. Where joints which do not coincide with supports occur in trays with folded over returns, tight fitting metal guide pieces, at least 450mm long, shall be inserted in the folded returns to provide the necessary support to the two cable tray ends. Splices as described above shall be provided if trays sag.

4.38.6.5 Fixing

4.38.6.5.1 Trays shall be bolted to supports by at least two hexagon headed bolts and nuts per support. Bolts shall be securely tightened to avoid cables being damaged during installation. The use of square nuts may not be permitted.

4.38.6.6 Fixing to the structure

4.38.6.6.1 The supports for cable trays and ladders shall in all cases by securely fixed to the structure by means of heavy duty, expansion type anchor bolts. It is the responsibility of the Subcontractor to ensure that adequate fixing is provided since cable trays and ladders that work loose shall be rectified at his expense.

4.38.6.7 Accessories

4.38.6.7.1 Horizontal and vertical bends, T-junctions and cross connections shall be supplied by the Subcontractor. The dimensions of these connections shall correspond to the dimensions of the linear sections to which they are connected. The radius of all bends shall be 1000mm minimum. The inside

dimensions of horizontal angles or connections shall be large enough to ensure that the allowable bending radius of the cables is not exceeded. Sharp angles shall have a 45º cornice.

4.38.6.8 Installation of cables

4.38.6.8.1 Cables shall be installed adjacent and parallel to each other on the trays with spacings as determined by the current ratings. Horizontal trays and ladders shall in general be installed 450mm below slabs, ceilings etc. to facilitate access during installation.

4.38.6.9 Earthing

4.38.6.9.1 Metal trays and ladders shall be bonded to the earth bar of the switchboard to which the cables are connected. Additional bar copper stranded conductors or copper tape shall be bolted to the tray or ladder where the electrical continuity cannot be guaranteed.

4.38.7 **Cable Trunking**

4.38.7.1 **Construction**

4.38.7.1.1 Cable trunking shall consist of butting sections constructed from high grade sheet steel having a minimum thickness of 1,6mm.

4.38.7.1.2 It shall be rust proofed by an approved metalising process, finished with one coat of rust resisting paint and one coat of high grade stove enamel.

4.38.7.1.3 The lids of the trunking shall be made from the same material, shall be removable over the whole length of the trunking and secured at centres not greater than 450mm.

4.38.7.1.4 Adjoining lengths of trunking shall be correctly aligned and the two sides at right angles to the cover shall each be joined to the corresponding sides of the adjacent trunking by means of internal fishplate connectors.

4.38.7.2 Installation

4.38.7.2.1 Support of cable trunking shall be at least as follows:

Trunking Size	Maximum spacing of Hangers and Fixings
Up to 76 x 76mm	600mm centres
Up to 150 x 76mm	1 000mm centres
Up to 380 x 200mm	1 200mm centres

4.38.7.2.2 The trunking shall be mechanically continuous throughout. At each joint in the trunking continuity shall be maintained by the installation of copper or brass links secured by brass nuts, locking washers or bolts. Self-tapping screws will not be acceptable.

4.38.7.2.3 All tees, reducers, angles and other accessories for trunking shall have folded and welded corners.

4.38.7.2.4 All trunking bends shall be of easy sweep design with fillet corners, and where branch or cross-over connections are made the edges of the apparatus shall be rendered smooth with approved edging strips.

4.38.7.2.5 Where trunking is not directly fixed to surfaces it shall be hung from straps or rod hangers arranged to support the trunking rigidly in both directions.

4.38.7.2.6 Where inverted trunking is used the cables shall be retained in their individual compartments by clips at not less than 1m intervals. Groups of cable shall be secured within the trunking with plastic tape.

4.38.7.2.7 The Electrical Subcontractor shall arrange his layout of trunking in conjunction with other trades and no work shall commence until the Electrical Subcontractor has verified that his trunking will not clash with the services of other trades by means of co-ordination Drawings to the Engineer's approval.

4.38.7.2.8 Adequate allowance shall be made for expansion and contraction on all runs and where the trunking passes over expansion joints in the building structure, expansion couplers shall be provided.

4.38.7.2.9 Care shall be taken to ensure that water, concrete and other foreign matter are not allowed to enter trunking particularly where trunking is cast into or through structural concrete or floor screeds.

4.38.7.3 **Coverplates**

4.38.7.3.1 All channels up to 125mm wide shall have snap-in cover plates of metal or P.V.C. Cover plates for wider channels shall be of metal and shall be fixed by means of screws which shall permanently be tapped into the cover plates spaces at suitable intervals to prevent warping. The finish of the covers shall comply with paragraph 4.10.9.

4.38.7.4 Connections

4.38.7.4.1 Adjoining lengths shall be correctly aligned and securely joined by means of fishplates and mushroom bolts, washers and nuts or connection pieces that are pop-rivetted to both adjoining sections. All adjoining sections shall be rectangular and shall butt tightly. Covers shall fit tightly across the joint.

4.38.7.5 Vermin proofing

4.38.7.5.1 All cable channels shall be vermin proof after installation. Holes shall be covered by means of screwed metal plugs or by means of metal strips that are bolted or pop-rivetted to the channel. Wooden or other plugs which are driven into holes or other temporary plugs or covers are not acceptable.

4.38.7.5.2 When installing trunking the Subcontractor shall ensure that:-

4.38.7.5.3 When cut, filled or drilled, the connections shall be given one coat of approved anti- corrosive paint subsequent to the removal of all burrs.

4.38.7.5.4 When conduits enter trunking, the connection shall be made with two locknuts and a female brass bush.

4.38.7.5.5 All burrs caused by drilling or machines shall be removed prior to the installation of cables and the fixing of lids.

4.38.7.6 **Internal finishes**

4.38.7.6.1 All bends shall be of easy sweep design with 45º cornices. Burrs and sharp edges shall be removed and the inside edges of all joints shall be lined with rubber cement or other suitable rubberised or plastic compound to prevent conductor insulation laceration.

4.38.7.7 Services

4.38.7.7.1 Multiple duct runs or internal metal partitions shall be used where conductors for power, control and other services are present.

4.38.7.8 **Materials and finishes**

4.38.7.8.1 Cable ducts shall be of the "SANKEYSTRUT" type or similar. The ducts shall be rolled from 1,2mm minimum sheet steel and shall be finished as follows:

In coastal areas (under all installation circumstances)		hot-dipped galvanised to S.A.B.S. 763 or epoxy powder coating
Cast in concrete	- pre-galvanised	hot-dipped galvanised to S.A.B.S. 763 or epoxy powder coating
False ceiling voids	-	hot-dipped galvanised to S.A.B.S. 763 or epoxy powder coating
Surface mounted in plant rooms, substations, service tunnels, basements -		epoxy powder coating or electro-galvanised
Damp areas, exposed to weather, underground runs in contact with earth		hot-dipped galvanised to S.A.B.S. 763 or epoxy powder coating
Undercover industrial applications		hot-dipped galvanised to S.A.B.S. 763 or epoxy powder coating

4.38.7.8.2 Hot-dipped galvanised or electro-galvanised ducts shall be cold galvanised at all joints, sections that have been cut and at places where the galvanising has been damaged. Powder coated ducts shall likewise be touched up at joints, cuts and damaged portions using spray canisters recommended by the manufacturers of the channels.

4.39 INSTRUMENTS

4.39.1 Provide and install instruments where shown on the applicable Drawings or mentioned herein as follows, the instruments to be fully metricated to local standards. All instruments shall be installed within Plant rooms where possible and shall be mounted at eye level and, if necessary, remote sensors shall be provided to ensure eye level accessibility. All instruments shall be installed in positions not affected by Plant vibration.

4.39.2 Instruments shall be of the circular dial type, having equal sized dials between 75mm and 100mm in diameter, unless otherwise specified, and the same finish in either stainless steel or chrome plated. All panel mounted instruments shall be suitable for flush mounting and fixing from within the panels without screws projecting through the panels.

4.39.3 Instruments shall be provided with pointers or have painted on their dials green lines to indicate the normal operating ranges of the services indicated and red lines to indicate any minimum and/or maximum limits.

4.39.4 Air and water temperatures shall be measured with stem or remote bulb type thermometers which shall have a guaranteed accuracy within 1% around the entire dial range and a means for recalibrating the instruments on Site. Thermometer ranges shall be suitable for the service and shall not exceed 50% above or below the normal operating temperatures for each instrument.

4.39.5 Stems or bulbs sensing temperatures in pipes shall be fitted into oil filled brass wells and bulbs in ducts or plena shall be neatly fitted on insulated brackets to the satisfaction of the Engineer.

4.39.6 Bulbs sensing wet bulb temperatures shall be provided with suitable cotton socks and copper/brass wet bulb tank with ball float make-up piped to raw mains water supply, overflow and drain connection, the latter piped to drain. Wet bulb tanks shall preferably be the product of a control instrument manufacturer. Two spare cotton wicks per wet bulb sensor shall be provided.

4.39.7 Water pressure gauges shall be glycerine filled Bourdon tube type, scaled from 0 to 150% of operating pressure and of steam quality and first grade accuracy. Each pressure gauge shall be preceded by a siphon tube and high quality gauge cock.

4.39.8 Orifice plates complete with cocks shall be provided and installed at all positions necessary to enable readings to be taken of water flow quantity. The orifice plates shall fit between flanges in the water piping and be provided with permanently affixed brass engraved plates indicating orifice diameter. Orifice plates shall be as supplied by NEGRETTI & ZAMBRA and sized to use standard water flowmeters as procurable from the firm from which orifice plates are purchased. The Subcontractor shall note that he shall be responsible to set water quantities by use of the orifice plates and shall therefore be in possession of a portable flowmeter suitable for the orifice plates he installs.

4.39.9 Air pressure gauges shall be 50mm dial scaled from 0 to 150% of normal operating pressure, equal to JOHNSON CONTROLS manufacture.

4.39.10 Static pressure indicators shall be of the diaphragm actuated, dial and pointer type graduated to read from 0 to 50% more than the maximum allowable static pressure and shall be installed to sense the leaving main supply duct pressure. The gauges shall be connected to static pressure tips of approved design.

4.39.11 Kilowatt-hour meters shall be of the house service type, approximately 162 x 112 x 100mm deep, of robust construction, housed in a dust proof sealed metal or plastic case, shall utilise a magnetic suspension for the disc and shall comply with BSS 37.

4.39.12 The meter element shall be suitable for operation on single phase, or three phase as specified, 50 Hertz AC system and shall be of the indicator type, capable of continuously carrying the rated current. Accuracy shall be "Commercial Grade" as defined in S.A.B.S. 01.

4.39.13 The registering mechanism shall be of the cyclometer type giving a reading of six figures, the lowest indicating tenths of a unit.

4.39.14 The meters shall be suitable for the supply voltage specified and the rated current shall be as directed.

4.39.15 Voltmeters shall be of the moving iron flush mounting type, rectangular or circular and size as specified. They shall be suitable for vertical switchboard mounting and studs shall be provided for back connection. The voltmeters shall be suitable for operation on a 50 Hertz system, and be calibrated as required. The voltmeters shall be manufactured in accordance with BSS 89 to industrial grade accuracy as specified therein.

4.39.16 The voltmeters shall be protected by high rupturing capacity cartridge fuses to S.A.B.S. 172 : housed in suitable insulated fuse carriers with a panel-mounted base. Voltmeter selector switches shall be incorporated.

4.39.17 Ammeters shall be and of the moving iron flush mounting type and of the pattern, size and scale range as specified. Ammeters for use in motor circuits shall have a suitably compressed overload range.

4.39.18 Ammeters selector switches shall be installed if specified. Selected switches having spring loaded contacts running over copper segments are not acceptable.

4.39.19 Combined maximum demand and indicating ammeters shall be flush panel mounting, rectangular in shape, the dial size being approximately 125 x 125mm or 80 x 80mm as specified. The ammeters shall comply with BSS 89.

4.39.20 The instrument shall comprise a moving iron ammeter showing the instantaneous current value, combined with a maximum ammeter employing a bimetallic spiral device which will indicate the mean current value on the basis of a 15 or 30 minute period as noted, and which is fitted with a residual pointer to indicate the maximum mean current reached during any period between manual resetting.

4.39.21 All three indications shall be registered on concentric scales, and instruments having small moving iron ammeters with window cut-outs scales are not acceptable. The bimetallic system shall incorporate ambient temperature compensation.

4.39.22 The instrument shall be used with a current transformer having a 5 ampere secondary winding. 6 Ampere or 8 ampere instruments may be offered, scaled to the full load primary current of the current transformers, with an additional overload scale in the case of 6 amp instruments.

4.39.23 Power factor indicators shall be housed in pressed steel cases. Shadowless scale plates shall be fitted. Instruments shall comply with BS 89. Indicators shall be suitable for flush mounting in switchboards. Current rating shall be 0,5 to 5 A continuous at the rated voltage. Power factor range shall be from 0,5 PF lead to 0,5 PF lag, and size shall be as specified.

4.39.24 Elapsed time meters shall be of the flush mounting type, square phenolic frame, suitable for switchboard mounting. Registers shall be calibrated in hours and tenths of hours. Cyclometer details to be noted. Voltage range shall be 200 - 250 V 50 Hz unless otherwise noted. Motors shall be self-starting, synchronous, non-reversing and shall be energised from the same supply as the apparatus being metered.

4.39.25 Transducers shall be suitable for use in remote indication systems for alternating current and voltage using lightweight telephone type pilot wires. Outputs shall be suitable for operating moving coil instruments and recorders.

4.40 EQUIPMENT BASES

4.40.1 Provide, as called for in the detailed specification or as indicated on the Drawings, equipment bases of the applicable type as specified below:

4.40.2 Inertia bases shall comprise a reinforced concrete pad of mass one and a half times that of the equipment to be mounted upon it. A welded mild steel tray, suitably reinforced and of sufficient depth to contain the required weight of concrete, shall be provided by the Subcontractor. Welded into such trays shall be a suitable template complete with the necessary ragbolts suitable for rigidly affixing the equipment to the base, once concrete has been cast in it. The Principal Contractor will pour concrete into the tray and smooth plaster it with coloured granolithic finish. The steel tray is to be positioned on a 80mm high smooth plastered "housekeeping" plinth, such plinth provided by the Principal Contractor and 150mm larger than the steel tray all round. The inertia base shall be separated from the plinth by suitable vibration isolators, as later detailed, proper provision in the design and construction of the steel tray being made for the attachment of the necessary vibration isolating mountings.

4.40.3 Floating steel bases shall be shop-fabricated from mild steel channel sections of sufficient strength and rigidity using welded joints. Such bases shall, unless otherwise called for elsewhere or noted on Drawings, be of rectangular shape and at least 80mm larger in all plan dimensions than the equipment to be mounted onto it. The construction of the base shall be such that proper provisions are incorporated for attaching laterally or fitting beneath it, vibration isolators of the type which each application may require. The Principal Contractor will provide a level plastered 80mm high "housekeeping" plinth on which to mount the aforementioned steel base, the plinth to be 100mm minimum larger than the base all round.

4.40.4 Static plinths, 80mm minimum high, shall be provided by the Principal Contractor for mounting non-vibrating equipment upon them, the plinths to be rectangular in shape unless otherwise shown on the Drawings and 100mm larger all around than the equipment to be mounted upon them.

4.40.5 The Subcontractor shall provide and position, where required, a channel iron frame, with mitred welded corner joints, and sheet-metal bottom tray for the Principal Contractor to fill with concrete. The finish of the plinths shall be tinted granolithic.

4.40.6 Anti-vibration mountings shall be utilised in conjunction with the aforementioned bases, as relevant and as indicated on the Drawings, for the following listed items of equipment.

4.40.7 All anti-vibration mountings shall be installed in full accordance with their manufacturer's application instructions, the model numbers mentioned herein referring to equipment of Mason Industries Inc., although other approved makes would also be acceptable.

Equipment	Minimum Static Deflection	Type of Mounting	Model
Centrifugal chillers and Reciprocating Compressors/Chillers	50mm	Helical spring with levelling adjustment	SLF
Cooling Towers over or non-occupied areas		Neoprene Vibration Pads	NK WMW
Over occupied areas with levelling adjustment	To suit fan speed	Restrained Helical spring	SLR
Centrifugal Pumps or over non-occupied areas		Neoprene Vibration Pads	NK WMW
Over occupied areas	25mm	Helical Spring with levelling adjustment	SLF

Equipment	Minimum Static Deflection	Type of Mounting	Model
Fans			
Up to 500 rpm 500 to 1200 rpm Above 1200 rpm	65mm	Helical Spring with levelling adjustment	SLF
Axial Flow Fans	6mm	Neoprene in sheer and compression	3ON
Air Conditioning units Air Handling units and Condensing units on concrete floors or bases	To suit fan speed	Neoprene Vibration Pads	NK or WMW
Air handling units and Air Conditioning units over occupied areas	To suit fan speed	Helical spring with levelling adjustment	SLF
Minor rotating and equipment in non-critical areas	6mm	Neoprene in sheer compression	N

4.40.8 Full details of all floating steel bases and all anti-vibration mountings selections shall be approved by the Engineer prior to the mountings being ordered and the bases fabricated.

4.40.9 Where applicable, the Subcontractor shall exercise particular care to prevent damage to the roof slab waterproofing when hoisting, positioning and connecting plant and equipment and shall note that he will be held responsible to repair any damage caused as a result of this installation.

4.40.10 All equipment and particularly that which is mounted on the roof shall operate without objectionable noise or vibration being transmitted to the full satisfaction of the Engineer.

4.41 EQUIPMENT SUPPORTS

4.41.1 Where equipment supports, stands, platforms and suspension brackets are indicated, specified or necessary for ductwork, pipework, tanks, air handling units, cooling towers, etc., the Subcontractor shall provide supporting structures capable of carrying the load without distortion, affixed to the building structure in such a manner as not to subject it to undue stress.

4.41.2 Supporting of any rotating equipment shall incorporate vibration mountings of the type and selection specified in the applicable clauses referring to equipment bases herein.

4.41.3 All methods of suspension or supports shall be submitted to the Engineer for approval and for reference to the Structural Engineers where necessary, prior to manufacture or installation.

4.41.4 Generally, supports shall preferably be proprietary products such as Unistrut or failing this, shall be of mild steel sections, purpose fabricated for their application. Under no circumstances whatever will sheet metal straps be accepted as a supporting method. All supports shall cradle the item to be supported; supports shall not be riveted or welded to the equipment to be carried except in exceptional circumstances approved by the Engineer. Rod hangers shall not exceed one meter in length and be of minimum diameter 12mm. For longer suspensions use mild steel angles. Angle iron supports shall be of 38mm x 5mm minimum. All supporting structures for equipment located in unprotected areas shall be hot dip galvanised.

4.41.5 Fastening methods shall employ REDHEAD or RAWBOLT anchor bolts or their equivalent, for fixing supports to the building structure, it not being permissible to utilise gunpowder shotdriven bolts for this purpose unless prior approval be obtained.

4.41.6 Pipework supporting holderbats shall be the product of a recognised manufacturer of such equipment, shop-fabricated saddles or similar devices being unacceptable unless limited space available necessitates their use. On insulated pipework, hardwood inserts consisting of two half-round machine cut pieces of timber shall be clamped around the pipe, insulation being cut away at any such points, to allow proper support fitting. Wooden inserts shall be of the same thickness as adjoining insulation and 50mm longer than the width of the holderbat support, to permit correct finishing of the insulation or vapour sealing to them.

4.41.7 Flexible pipes shall be supported on Unistrut or equivalent perforated galvanised cable tray, manufactured by specialists, shop-fabricated trays or racks not being acceptable. The cable tray shall be suspended or bracketted using suitable mild steel angles.

4.41.8 Reference shall be made to manufacturer's requirements regarding equipment supports and these requirements shall be fully complied with.

4.42 NOISE AND VIBRATION

4.42.1 Particular care shall be taken in the selection, application and installation of all equipment used to ensure that if operates below the maximum allowed noise levels, as specified in Part Five hereof, and with the least vibration possible, all to the full satisfaction of the Engineer.

4.42.2 The following measures shall be taken where necessary, whether specifically called for or not, all to ensure quiet vibration-free operation of the equipment forming part of the air conditioning and ventilation installations.

4.42.3 Rectangular ductwork in the vicinity of critical areas shall be provided with internal acoustic insulation.

4.42.4 Anti-vibration cuff connections or flexible joints shall be used on ductwork where it joins vibrating equipment such as fans and air conditioning units.

4.42.5 Pipework connecting rotating or vibrating machinery shall be provided with anti-vibration flexible joints, all as previously specified.

4.42.6 Equipment shall be mounted on vibration isolators of the correct type and selection, dependent upon deflection requirements versus vibrating frequency.

4.42.7 Pipework and ductwork shall be suspended or mounted using suitable supports with vibration isolators to prevent transmission of vibration from them to the structure to which they are attached, where necessary only.

4.42.8 Suitable sound attenuating devices shall be incorporated within ductwork to reduce airborne noise to acceptable levels, as indicated on the Drawings and specified in Part Five hereof.

4.42.9 The Subcontractor shall provide sound level data to the Engineers on the completion of the installation detailing the noise levels in octave bands for each separate air conditioned and ventilated areas.

4.42.10 Noise measurements for the sound level data shall be taken during full or nearly full cooling load conditions by an approved organisation. No measurement shall be taken closer than 1 meter from any outlet, ceiling, wall or floor surface.

4.42.11 If, in the opinion of the Engineer, any equipment operates with, or transmits from it, objectionable vibrations or noise above the levels specified for the individual areas, it will be necessary to rectify or replace such equipment to the full approval of the Engineer at no additional cost to the Owners.

4.43 PAINTING AND CLEANING

4.43.1 No untreated metal surfaces shall be permitted on the project. Items which are not galvanised or similarly protected against rust and corrosion shall be painted, as later detailed herein. No equipment, hangers, brackets etc., shall be permitted to be delivered on site in unprotected form; they shall be factory-coated with an approved zinc-rich prime coat before despatch from their place of manufacture.

4.43.2 Painting shall comprise the following consecutive processes. First thoroughly clean, descale and degrease all surfaces, in accordance with acknowledged good practice, follow with a good coating of approved zinc-rich primer and one coat of universal undercoat, finish with two coats of quality high-gloss enamel of an acceptable make. Final finish shall be to the full approval of the Engineer.

4.43.3 With the exception of certain air conditioning piping, items with a galvanised finish, such as cable trays, need not be painted but shall be properly cleaned with a suitable proprietary galvanised iron cleaning fluid. Where galvanised finish is painted, it shall be primed with a Calcium Plumbate Primer.

4.43.4 Particular care shall be taken that appropriate primers be used as a basis for painting and that paint be of high quality manufacture, all to provide a completely satisfactory finish to the approval of the Engineer. It shall be noted that galvanised surfaces are to be treated to ensure proper bonding of paint.

4.43.5 Whereas it would not be necessary to paint any ductwork, conduits or pipework installed in roof voids, shafts, masonry ducts, etc. or where not normally visible, it is a requirement that such equipment be properly cleaned, treated with two coats of rust-proofing paint if not galvanised or not metal subject otherwise to rust.

4.43.6 Where the inside of ducting is visible through grilles and diffusers or any other openings the visible section of the interior of the duct shall be painted matt black after degreasing and priming as specified above.

4.43.7 All plant and equipment on the project shall be painted and colour-coded in accordance with standards recognised in the Republic of South Africa and, where possible, to comply with relevant South African Bureau of Standards Colour Codes, or as later specified herein.

4.43.8 All plant and equipment shall be painted in accordance with a colour code given and where factory painted items such as the Air Conditioning Units, Cooling Towers and Pumps are not painted a colour similar to that specified they shall be repainted by the Subcontractor.

4.43.9 Factory painted equipment which is required to be repainted to comply with the specified colour code shall be rubbed down prior to being given two coats of gloss enamel paint, or as required in accordance with the paint manufacturer's recommendations and depending upon the type of paint applied at the factory.

4.43.10 On completion of the installation the Subcontractor shall clean all equipment properly, remove all superfluous materials from the site, make good black granolithic finished equipment bases with black concrete paint, sweep out Plant rooms and make the Plant completely presentable before calling upon the Engineers to accept the plant as finalised, after completion of the "Preliminary Tests".

4.44 LABELLING AND IDENTIFICATION

4.44.1 All equipment shall be labelled and identified using white Traffolite labels having 10mm high black lettering engraved on them; where two similar items exist, they shall additionally be numbered for clarity in identification. Labels shall be neatly riveted or secured using epoxy based glue, no other type of adhesive being acceptable.

4.44.2 Prepare a complete piping diagram for the complete installation also showing drains, vents, etc., and give every valve on the project a designation. Fit every valve with an identification tag of engraved plastic or aluminium 3mm thick, 40mm diameter, such tag affixed to the valve with key tag type ball chain of chromium plated finish. The aforementioned piping diagram shall form part of plant operating instructions later referred to in this Specification.

4.44.3 Designate and identify each automatic control device such as 3-way valve, thermostat, damper motor, etc., and fit to each a white Traffolite label having 5mm high black lettering, the labels glued on with epoxy-based adhesive. Prepare a complete control diagram of the installation and label with relevant designations mentioned above, all to form part of plant operating instructions which are later mentioned herein.

4.44.4 Identify pipes, ducts, equipment, by colour coding as previously mentioned herein. In addition to this label pipes and ducts with directional arrows neatly stencilled onto finished paintwork or in the form of a durable proprietary transfer. Arrows shall be at not more than 5 meter intervals and not less than 100mm long, of good colour contrast to equipment colour background.

4.44.5 Belt guards and items of plant containing belt driven equipment shall be fitted with a label stating the number of and sizes of the belts for each vee belt drive. The labels shall be of the same type and dimensions and shall be fixed as specified for all equipment.

4.44.6 Designate and identify each automatic control device such as 3-way valve, thermostat, damper motor, etc., and fit to each a white Traffolite label having 5mm high black lettering, the labels glued on with epoxy-based adhesive. Prepare a complete control Diagram of the installation and label with relevant designations mentioned above, all to form part of plant operating instructions which are later mentioned herein.

4.44.7 Identify all Plant rooms as "Air Conditioning" or "Air Handling Plant Room" with 5mm thick engraved P.V.C. sheet notices having 25mm high black lettering on a white background.

4.44.8 Provide and install all necessary notices required in terms of Governmental and Local Authorities' laws, such as "No Entry to Unauthorised Person", at all Plant room entrance doors, etc. Such notices to be silk-screened onto 3mm minimum thickness P.V.C. sheet, as obtainable from Messrs. Mine Safety Appliances.

4.44.9 On multiple split systems pipework identification shall be installed at approximately 3 metre intervals.

4.45 COMMISSIONING AND TESTING - PRELIMINARY TESTS ON COMPLETION

4.45.1 Following completion of the Works, or any portion of the Works as specified or directed by the Engineer, the Subcontractor shall balance, set and test the Works, or portion of the Works, in accordance with the following requirements, to establish the capacity and satisfactory performance of the Plant.

4.45.2 All balancing, settling and testing shall be done by the Subcontractor entirely at his own expense. The Subcontractor shall provide all facilities and apparatus for the testing of the Plant and shall carry out such tests as may be necessary to satisfy the Engineer that the Plant meets with the requirements of the Specifications.

4.45.3 The Subcontractor shall also carry out or attend upon all tests required by Government and Local Authorities who have jurisdiction over the Works and shall obtain all necessary certificates of approval and acceptance and provide the Engineer with triplicate copies of all such certificates prior to or at such time as, providing the Engineer with copies of his "Preliminary Test" report.

4.45.4 All test instruments shall be checked for accuracy by the manufacturers, suppliers or approved laboratory and certified copies of certificates showing the degree of accuracy shall be supplied to the Engineer together with the "Preliminary Test" reports.

4.45.5 Gauges, thermometers, ammeters and other instruments specified as part of the permanent Plant may be used for test purposes providing that the Subcontractor ensures that all such instruments are accurately calibrated. The Subcontractor shall check the accuracy and calibrate all such instruments against laboratory tested instruments.

4.45.6 The Subcontractor shall when required, provide the Engineer with equipment selection and performance data for all major items of plant, such as Air Conditioning Units, Air Handling Units, Cooling Towers, Pumps, Fans and Sound Attenuators.

4.45.7 The Subcontractor shall keep full and proper written records of all tests conducted and commissioning information, such data to be properly indexed and clearly set down to form part of the Operating and Maintenance manuals called for in the Specification.

4.45.8 The Engineer reserves the right to inspect any item of equipment during manufacture or before delivery to Site. The Subcontractor shall make available any item for such inspection.

4.45.9 Electrical switchpanel shall be inspected by the Engineer at their place of manufacture, prior to delivery to Site. At such inspection and testing, the Subcontractor shall demonstrate the functioning of the switchpanel to the Engineer. Any defects in materials, finishes and operations of the switchpanel shall be corrected at their place of manufacture prior to delivery to Site.

4.45.10 The Subcontractor shall, on handing over the Installation or any portion thereof, to the Engineer, also provide the necessary certificates as proof of having conducted a satisfactory electrical test to the requirements of the electricity supply authority, such certificate emanating from such authority and permitting full use to be made of the installation without the need for further tests.

4.45.11 The Subcontractor shall properly test and call for inspection by the Engineer, any work which is to be covered, concealed, built-in, otherwise closed up or rendered inaccessible, before such closing up takes place. The Engineer may require any work of this nature which he has not been called on to inspect before closing up, to be uncovered or made accessible to its inspectors entirely at the Subcontractor's expense, making good included.

4.45.12 Prior to the "Final Tests", to be attended by the Engineer, the Subcontractor shall balance, set and test the following to establish the capacity and performance of the Plant. All such "Preliminary Tests" shall be recorded by the Subcontractor who shall provide the Engineer with three typed copies of all test

recordings which shall set out the procedure, data and instrument readings obtained as compared with the specified capacities and the manufacturer's name plate ratings where applicable. Such preliminary test reports shall be accompanied by one preliminary draft set of Operating and Maintenance Instructions prepared in accordance with the requirements as detailed herein.

4.45.13 On receipt of an acceptable preliminary latest report and draft copy of the Preliminary Operating and Maintenance Instructions the Engineer shall advise the Subcontractor in writing that he may arrange for the final acceptance tests.

4.45.14 The "Preliminary Tests" shall include the following:

Completed sections of water pipework shall be tested with water pressure of not less than 700kPa or 50% above the maximum working pressure, whichever is greater, at the lowest point in the system. Care shall be taken to avoid putting excessive pressures on mechanical seals, safety devices etc., which are not designed to withstand pressures used in tests. The system shall be filled and all air vented before the actual test pressure is applied. Test pressure shall be applied when water and average ambient temperatures are approximately equal and constant. Test pressure shall be maintained for not less than 30 minutes without appreciable drop after the force pump has been disconnected. Leaks in screwed fittings shall be corrected by remaking the joints. Leaks in welded joints shall be cut out and rewelded and not caulked. All testing must be performed and systems approved prior to covering or concealing piping.

On completion of the entire installations, all water circulating systems shall be flushed and balanced to provide the water quantities circulated through all heat transfer equipment as specified or required to provide the capacity specified. All temperature control valves shall be fully open during balancing and all regulating valves shall be permanently marked at the final settings. All balancing valves shall have their handwheels removed and stored, with the Spare Parts on completion of the tests.

Drains shall be tested for proper functioning by pouring water down them at a rate of at least four times normal drainage quantity.

Compressed air piping, except low pressure control piping, shall be tested at not less than 1000kPa. This pressure shall be maintained for one hour without pumping. A correction of the final pressure of not more than 13kPa for each 3ºC change in average ambient temperature during the test will be permitted. Leaks shall be corrected as specified for water piping.

Low pressure temperature control air piping shall be tested with 200kPa air pressure. This pressure shall be maintained for one hour without pumping during which time the pressure shall not drop more than 8kPa. A correction of the final pressure of not more than 3,5kPa for each 3ºC change in average ambient temperature during the test will be permitted. Leaks shall be corrected by remaking the joints and not by caulking.

Field assembled refrigerant piping and apparatus shall be tested with dry carbon dioxide or nitrogen plus a small amount of refrigerant. Test procedures shall be in accordance with the latest edition of the American Standard Safety Code for Mechanical Refrigeration. Leaks in pipe joints shall be4 corrected by remaking the joints. Caulking will not be permitted. The vacuum test shall follow the pressure test.

Charging of the equipment with refrigerant shall follow the vacuum test as closely as is practicable to minimise the possibility of air or moisture being returned to the system. After charging and prior to capacity tests, joints in refrigerant piping and apparatus shall be checked with a halide torch or other equally sensitive leak detector. If leaks are found, the system shall be pumped down and the leaks corrected.

Capacities of Refrigeration Machines, Cooling Towers, Pumps, Air Conditioning Units, Air Handling Units, Condensers, Heaters, Fans and other equipment shall be determined by operating tests of not less than four hours duration, after stable conditions have been established. Test procedures shall be in accordance with applicable portions of ASME and other recognised test codes as far as field conditions permit. Capacities shall be based on temperatures and air and water quantities measured during such tests.

Water quantities shall be measured with calibrated orifice or venturi type flow meters. Water quantities read from pump curves shall not be used for determining capacities.

Temperature differences required for determining capacities shall be measured by thermometers having graduations that permit interpolations having an accuracy of plus or minus 0,5 degrees C.

Air quantities may be measured by pitot tube, anemometer or velometer, depending on the velocity and other conditions of flow.

Check alignment of all equipment drives prior to setting into operation.

Air systems shall be checked for obstructions and balanced to provide the required air quantities at each outlet without objectionable noise and draughts and so that the velocity of the air is relatively uniform over the area of the outlet.

Velocity meters may be used to test all outlets and for duct velocities up to 1,55 m/s, above which velocities shall be measured with Pitot tubes. Properly capped openings shall be provided in ducting as required. Final settings of all volume adjusting devices shall be permanently marked.

Air duct systems shall be adjusted and balanced so that air quantities at outlets are as specified, further, the distribution from supply outlets is free from drafts, and uniform over the face of each outlet.

The entire air distribution system shall be adjusted and balanced in accordance with the "Manual for Balanced Adjustment of Air Distribution System" as compiled by SMACNA.

Air quantities specified for fans include for duct leakage. The sum of the air quantities of all outlets would normally be accepted at a tolerance of plus or minus 5% of that specified for the fans.

The air quantities at the terminals would normally be accepted at a tolerance of plus or minus 10% provided the total air supplied to the particular space is within a tolerance of plus or minus 5%.

Airflow quantities shall not be reduced by artificially increasing the system resistance by more than plus or minus 5% of the total system resistance.

4.45.15 Airflow quantities shall be determined by a combination of the following:

- o Airflow by means of anemometer over filter bank or coil.
- o Main duct airflow by means of a pitot tube traverse.
- o Pressure differential across and power consumption of fan.
- o Supply air quantity at terminals using a calibrated hood.

4.45.16 Should it be necessary to re-balance any air system due to partitioning or repartitioning of the conditioned space after the specified conditions have been obtained and accepted by the Engineer, then such re-balancing shall be carried out as an extra to the Subcontract and shall be authorised, by the issue of a "Variation Order", by the Engineer.

4.45.17 Sound tests to demonstrate compliance with sound guarantees shall be made at locations selected by the Engineer.

4.45.18 Sound levels shall be measured with sound meter complying with the latest American Standards Association. The "A" scale shall be used for overall sound level readings. Where sound levels are specified in octave bands, the above sound level meter shall be supplemented by an Octave Band Analyser complying with the latest American Standards Specifications for an Octave Band Filter Set No.

Z24.10, published by the American Standards Association. The sound level meter shall be set on the "C" scale of all octave band readings.

4.45.19 "Equipment components" of room noise levels (those portions of total room noise levels attributed solely to air conditioning equipment) shall be determined at any point within a room not less than 1,8 meters from air terminals.

4.45.20 Sound level readings shall be taken on a Sunday morning when the building is unoccupied and when activity in surrounding areas, and background noise levels in areas tested, are at a minimum and relatively free from sudden changes in noise levels. Readings shall be taken with no equipment operating and with all air conditioning equipment, capable of transmitting sound to the space tested, in operation.

4.45.21 All automatic controls and safety devices shall be checked for correct performance and satisfactory operation and set to the respective settings required, such settings to be recorded.

4.45.22 All electrical switchpanel shall be checked for the correct functioning of all components and electrical interlocks and all time clocks, time delay relays and automatic control devices shall be set for their correct function.

4.45.23 The running current of all electrically operated equipment shall be recorded and compared with the manufacturer's name plate ratings, which shall be recorded together with any other relevant data stamped on the name plates. All overload protection devices shall be set to the correct values, which shall be recorded.

4.45.24 The Subcontractor shall ensure that the plants operate satisfactorily and uninterruptedly for a period of 7 days prior to final acceptance by the Engineer. Evidence of this, for air conditioning systems, shall be given in the form of 24 hour long continuous recordings of temperature and humidity, which recordings shall cover at least 50% of the areas handled by any one plant and shall be handed over to the Engineer prior to inviting him to the Final Tests and acceptance of the completed installations.

4.45.25 The original recorder graphs shall be supplied to the Engineer and the Subcontractor shall also obtain and provide the Engineer with the daily maximum dry and wet bulb temperature readings recorded in the area on the same days as the inside conditions are recorded. Such information may be obtained from local weather stations.

4.46 OPERATING AND MAINTENANCE INSTRUCTIONS

4.46.1 The Subcontractor shall furnish to the Engineer before the Works are taken over, such Operating and Maintenance Instructions, together with Drawings of the Works as completed, and in sufficient detail to enable the Employer to operate, maintain, dismantle, re-assemble alter and adjust all parts of the Works.

4.46.2 The Works shall not be considered to be completed for the purposes of taking over until the required Instructions and Drawings have been supplied to the Engineer.

4.46.3 A draft copy of all written instructions shall be submitted to the Engineer for approval together with the required copies of the "Preliminary Test" report, as previously specified herein, prior to the preparation of the final copies.

4.46.4 After approval of the draft manual, the sub-contractor shall submit three copies of the document in hard copy, bound in a hard cover with the details of the project clearly indicated on the spine. In addition, an electronic copy of the complete document on a CD and in pdf format shall be supplied together with electronic copies of all the as built drawings in dwg or dxf format. The CD shall be labelled and indexed.

4.46.5 The "Operating Instructions" shall include the following:

4.46.5.1 INDEX (in detail)

4.46.5.2 DESCRIPTION OF PLANT (as installed)

4.46.5.3 OPERATION OF PLANT (as installed) to include:

Automatic and manual start-up and shut-down procedure

Operation and Sequences of all automatic controls

Scheduled description of all Control and Safety Instruments listing function, make, model number, range and differential (when applicable), and setting of each instrument.

Functions of all switches, indication lamps, reset button and alarms, and instructions for adjusting and re-setting all controls and cut-out switches.

4.46.5.4 PLANT AND EQUIPMENT

Scheduled list of all major plant and equipment to include

- Description
- Make
- Model Number
- Supplier's name and address.

4.46.5.5 TEST REPORT

Copy of "Final Test" report as accepted by Engineer. (Draft copy of "Operating Instructions" for Engineer's approval may contain a copy of the "Preliminary Test" report).

4.46.5.6 MAINTENANCE INSTRUCTIONS

In schedule form setting out each item of plant, the description and frequency of the required maintenance operations as necessary for preventive maintenance of the Plant as installed.

4.46.5.7 SPARE PARTS

List of spare parts supplied (in accordance with these Specifications) and recommended with detailed description of each part, make, model or part number and supplier's name and address.

4.46.5.8 DESCRIPTIVE LITERATURE

To include manufacturer's operating and maintenance instructions, performance curves or charts and spare parts lists where applicable and when available.

4.46.5.9 DRAWINGS

List of all Drawings and photographically reduced, Size A3, copies of all "as installed" Drawings and Diagrams to include the following:

Plant layout Drawings showing the actual positions and sizes of all plant and equipment, ducts and pipes, the location of all dampers, valves and controls and the measured air quantities at all air intake and discharge points.

Control and Wiring Diagrams and Schematic Piping Diagrams noting, where applicable, the normal and abnormal gauge readings, control points, scale settings and time settings, differential bands, throttling

ranges, time delays and the overload settings and actual rated amperages of all electrical components, and any other relevant variable and adjustable items, to permit checking and adjustment of all instruments, controls and motor functions.

4.46.5.10 COPIES OF INSTRUCTIONS IN PLANT ROOMS

A copy of the "Operation of Plant" instructions shall be mounted within a glazed or plastic covered frame in the Plant Rooms, in positions to be approved by the Engineer.

Copies of the Schematic Piping Diagrams and the Control and Wiring Diagrams shall be mounted within glazed or plastic covered frames in the Plant rooms, in positions to be approved by the Engineer.

Copies of Government Acts and Local Regulations, as required, shall be mounted within glazed or plastic covered frames in the Plant rooms, in positions to be approved by the Engineer.

4.46.6 A plant log book shall be provided and handed over to the Owner. The log book shall be a hard covered book containing details of each item of machinery together with provision for making service notes.

4.46.7 The Subcontractor shall instruct the Owners in the correct operation and use of the Plants. For this purpose the Subcontractor shall allow for the time of a competent instructor for a total of 5 days and four return trips to the Site for the purpose of providing such instructions.

4.46.8 During this period the Subcontractor shall fully explain the layout, operation and maintenance of the plant to the Owners or the Owners' representatives.

4.46.9 At the conclusion of this period of instruction the Subcontractor shall obtain from each of the Owners, an acknowledgement, in writing, that the instruction has been properly given for the prescribed period. Two copies of the acknowledgement shall be forwarded to the Engineer.

4.47 MAINTENANCE

4.47.1 The Subcontractor shall maintain and service the Plant, in accordance with the following requirements for a period of twelve months calculated from the date of Taking Over or, in the event of more than one certificate having been issued by the Engineer, from the respective dates so certified.

4.47.2 During the "Maintenance Period" the Subcontractor shall service the Plant regularly at monthly intervals and make good any Defects in accordance with the provisions of the conditions of contract of these Specifications.

4.47.3 The Maintenance of the Plant shall be carried out during normal working hours and at each service the Sub-contractor shall attend to the following.

4.47.4 Report to an official nominated by the Employers on arriving and again on leaving the Works. Such person shall sign a monthly "Service Report" giving details of any Defects reported and made good, temperature readings taken, etc. A copy of each such "Service Report" shall be submitted to the Engineer by the Subcontractor within fourteen (14) days of each service.

4.47.5 Check the function of each item of the Plant including all automatic controls and safety devices for correct operation and lubricate, adjust, clean and/or replace components and ancillaries as necessary.

4.47.6 Clean all washable air filters and check all disposable media type air filters serving the air conditioning plants check for pressure drops, fitting additional filter material if required.

4.47.7 Drain cooling towers, air washers, etc., as relevant, clean their sumps thoroughly, clean all pump suction filters and thereafter refill with water.

4.47.8 Remove, clean and replace all strainers contained in all water pipework and pneumatic control systems.

4.47.9 Check all refrigeration systems for leaks, refrigerant dryness, sufficient oil in the compressors, sufficient refrigerant gas or any other defects and correct as required.

4.47.10 Check the electrical switchpanel replacing any burnt contacts or pilot lamp bulbs which have failed.

4.47.11 Take and record Wet and Dry Bulb temperatures in each of the conditioned areas and outside. Temperature readings shall be taken with a reliable calibrated psychrometer and all readings shall be recorded on the "Service Report".

4.47.12 Attend to any complaints made, with respect to the Plant, by the official nominated by the Employer, being the only other person authorised to instruct the Subcontractor or make any complaint, (other than the Engineer). No other person shall have any right to instruct or make any complaint to the Subcontractor.

4.47.13 While attending to any Defects and the Servicing of the Plant the Subcontractor shall not unduly disturb the functions of the occupants in the areas concerned.

4.48 ELECTRICAL SUPPLY

4.48.1 The Employers shall provide suitable 3 phase and/or single phase electricity supplies, in the positions indicated on the Drawings.

4.48.2 The 3 phase, 4 wire and earth electricity supplies shall be connected to the incoming terminals of the main isolator in the air conditioning plant switchpanel or in the air-cooled packaged air conditioners, as applicable.

4.49 MAINS WATER SUPPLY

4.49.1 Mains water supply connections, where applicable, will be provided at the position indicated on the Drawings, and the Subcontractor shall allow for the connection from the point indicated to the equipment supplied in accordance with these Specifications. Where not indicated, it shall be allowed that water will be provided within 3 meters of the point of connection to the equipment and terminated with a valve.

4.49.2 The mains water supply pipe shall have a nominal bore of not less than 25mm and shall be provided with a shut-off valve.

4.50 DRAINS

4.50.1 Provide all necessary drain piping laid to suitable falls from every item requiring such drainage. Such drains shall be run to the adjacent relevant drain points shown on the Drawings. . Where not indicated, it shall be allowed that the drain shall be run 5 meters from the point of connection to the equipment and terminated over a tundish supplied by the plumber.

4.50.2 Drainage pipework from air handling plant and in plantrooms shall be adequately sized, not less than 32mm and carried out generally in medium grade galvanised piping, all connections to equipment being effected with conical-faced unions or flanged.

4.50.3 All drains from cooling coil pans for condensate disposal shall be fitted with proprietary U-traps to prevent backflow or non-drainage due to negative air pressures.

4.50.4 Drainage pipework of longer than 4,5mm run shall be provided with cleaning eyes on all bends to facilitate maintenance.

4.50.5 Drainage pipework from split units and fan coil units shall be uPVC class 6 with solvent welded joints. The drains shall be not less than 25mm and shall be run individually. Where two or more drains connect, the minimum pipes size shall be 50mm.

4.50.6 Drains shall be run to a fall of at least 1:40 and shall be adequately supported to ensure tat the condensate drains completely and no traps are formed.

4.50.7 Under no circumstances shall drains be run into storm water drains.

4.51 EXCLUSIONS

4.51.1 The Tendered price shall specifically be understood to EXCLUDE all the following items, it being stressed that such items will be provided by others to details given by the Sub-contractor, as relevant.

4.51.2 The provision of all Plant rooms and equipment spaces shown on the Drawings, complete with level floors, lighting, suitable airtight access doors and any other builder's work, as relevant or as indicated on the Drawings.

4.51.3 The provision and making good of any openings required through walls, floors, ceilings and roofs, as well as any timber framing or flashing necessary for same. The sub-contractor shall clearly indicate the positions of the openings and liaise with the building contractor for the cutting and making good of the openings.

4.51.4 All concrete work associated with the provision of equipment bases as detailed herein.

4.51.5 Any item, comprised of timber, bricks, mortar or concrete which can reasonably be construed as builder's work, together with the building-in of any item required.

4.51.6 The architectural concealment of any equipment to be installed by the successful Tenderer. This would apply particularly to piping and ducting.

4.51.7 The provision of masonry shafts and ducts as shown on the Drawings, complete with smooth internal plastered finish.

4.51.8 All openings in glazing in windows for the installation of fans.

4.51.9 The provision of mains water supply points, each terminating in a gate type isolating valve within three meters of the equipment it serves.

4.51.10 Drainage points provided in the positions and of the sizes indicated on the Drawings, such drains for general equipment drainage and condensate disposal.

4.51.11 The bringing up and connecting to the incoming terminals of the main isolators in each switchpanel suitably rated 380 volt, 3 phase, four wire electricity supplies. 220 volts, single phase outlets for plugged equipment or terminating with a switched isolator for directly coupled equipment

4.51.12 Any other item mentioned in these Specifications or on the accompanying Drawings as being expressly for the provision of others.