GENERAL SPECIFICATION

FOR

AIR-CONDITIONING, REFRIGERATION, VENTILATION

AND

CENTRAL MONITORING & CONTROL SYSTEM

INSTALLATION

IN

GOVERNMENT BUILDINGS

OF

THE HONG KONG SPECIAL ADMINISTRATIVE REGION

2001 EDITION

(VOLUME II)

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C1.1 GENERAL

Filters shall have the specified performance and fire property in accordance with the test methods of one of the standards stated in Sub-section C1.2.

To improve indoor air quality and protect air conditioning equipment, outdoor air and re-circulated indoor air shall be filtered to remove dust, bacteria, pollens, insects, soot and dirt particles before it enters the air conditioning system. The following air cleaning devices, dependent on their compatibility with the general air conditioning system, shall be incorporated into the system as in-duct devices or be stand-alone devices.

C1.1.1 Particulate Filter

Particulate filters are the most commonly used air cleaning devices in buildings. They are classified into two general categories, pre-filters and final filters, according to the size of the particulate, which they catch and the energy required to send air through them. One or a combination of the filters shall be selected depending on the physical characteristics and levels of the dust to be controlled, the capacity of the system to overcome the associated pressure drop across the filter and the degree of indoor air cleanliness required:

Table C1.1.1 – (1) Types of Filters

<table>
<thead>
<tr>
<th>Stage</th>
<th>Nature</th>
<th>Filter Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-filters</td>
<td>Washable</td>
<td>Washable Panel Filters</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Automatic Viscous Filters</td>
</tr>
<tr>
<td></td>
<td>Disposable</td>
<td>Disposable Panel Filters</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Disposable Pleated Panel Filters</td>
</tr>
<tr>
<td></td>
<td>Renewable</td>
<td>Renewable Panel Filters</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Automatic Fabric Roll Filters</td>
</tr>
<tr>
<td>Final Filters</td>
<td>Disposable</td>
<td>Bag Filters</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cartridge Filters</td>
</tr>
<tr>
<td></td>
<td></td>
<td>High Efficiency Particulate Air (HEPA) Filters</td>
</tr>
<tr>
<td></td>
<td>Renewable</td>
<td>Automatic Recleanable Filters</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Automatic Recleanable HEPA Filters</td>
</tr>
</tbody>
</table>

The filters shall be cleaned or replaced on a regular basis according to the manufacturer’s instructions or when a maximum pressure drop is reached. To prolong service life, two stages of filtration are recommended for buildings designed with a central air handling system to prevent premature clogging and frequent replacement of the high efficiency filter as below:-
Table C1.1.1 – (2) Filter Efficiency

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Pre-filters</th>
<th>Final filters</th>
</tr>
</thead>
<tbody>
<tr>
<td>General occupied areas</td>
<td>Required</td>
<td>60-79 % efficiency</td>
</tr>
<tr>
<td>Heavy dirt loading areas</td>
<td>Required</td>
<td>80-89 % efficiency</td>
</tr>
<tr>
<td>Sensitive areas</td>
<td>Required</td>
<td>90-95 % efficiency</td>
</tr>
</tbody>
</table>

For particularly critical clean air requirements such as health care facilities, three filtration stages may be used with High Efficiency Particulate Air (HEPA) Filter being the third stage.

C1.1.2 Electrostatic Filter

For conditions where low pressure drop, energy saving and minimum servicing are concerned, electrostatic filters shall be used which can also deal with odour of low concentration level.

C1.1.3 Gas Filter

Gas filters are designed to remove contaminating gases from the air. Solid sorbents including activated carbons, molecular sieves, silica gel and activated alumina, each of which has a different adsorbing characteristic, shall be used to remove the various contaminant gases.

C1.2 STANDARDS

C1.2.1 Performance of Air Filter

The performance of air filters shall comply, where applicable, with one of the following standards :-


(b) Underwriters Laboratories UL 586 – Test Performance of High Efficiency Particulate, Air Filter Units.


(d) Eurovent 4/5 - Method of Testing Air Filters Used in General Ventilation.

(e) Eurovent 4/4 - Sodium Chloride Aerosol Test for Filters Using Flame Photometric Technique.

(f) Any other standard as required by the Architect to suit the particular project requirement.

C1.2.2 Fire Property of Air Filter
The fire property of air filters and its associated accessories shall comply with one of the following standards as well as the latest requirement of Fire Services Department:

(a) British Standard Institution BS 476 : Part 4 - Non-Combustibility Test for Materials.

(b) British Standard Institution BS 476 : Part 6 - Method of Test for Fire Propagation for Products, with Indices "I" ≤ 12 and "i₁" ≤ 6.

(c) Underwriters Laboratories UL 900 - Standard for Air Filter Units, Class 1 or Class 2.

(d) European Standard DIN 53 438 Part 3 - Response to Ignition by A Small Flame, Surface Ignition, Class F1.

C1.3 DRY REPLACEABLE MEDIUM TYPE FILTER

C1.3.1 Bag Filter

The air filter shall be of high efficiency, extended area, deep pleated, disposable type. The media shall be microfine glass fiber, which is reinforced by a laminated synthetic backing. It shall have a nominal width of 600 mm and the following average atmospheric dust-spot efficiency by ASHRAE Standard 52.1 – 1992 and initial resistance at 2.5 m/s face velocity, unless otherwise specified in the Particular Specification. The air filter shall be designed for the air velocity of 1.0 to 3.5 m/s and shall operate to 250 Pa final resistance.

<table>
<thead>
<tr>
<th>Average Efficiency Not Less Than</th>
<th>Initial Resistance Not Exceeding</th>
</tr>
</thead>
<tbody>
<tr>
<td>65 %</td>
<td>75 Pa</td>
</tr>
<tr>
<td>85 %</td>
<td>100 Pa</td>
</tr>
<tr>
<td>95 %</td>
<td>145 Pa</td>
</tr>
</tbody>
</table>

The filter package shall be factory assembled as a complete set readily for site installation. The filter assembly shall consist of a holding frame, sealer frame, media retainer, and the disposable element.

The sealer frame shall be constructed of galvanized steel of sufficient thickness and be equipped with suitable airtight sealing gasket and sealing mechanism on the sealer frame flange. The media retainer shall be designed to match the filter elements to provide sufficient support for the multiple pleats of the filter element against the direction of the airflow. The media retainer shall be suitably coated and designed to totally eliminate the possibility of oscillation and sagging. The bag or packer shall inflate fully, shall not sag or flutter or be obstructed by contact with other filter faces or
ductwork surfaces when operation between 60 - 110% of design air volume flow rate for fixed volume system.

C1.3.2 Cartridge Filter

This type of filter shall work reliably in the range of medium and high cleaning efficiency. It shall have the following average atmospheric dust-spot efficiency by ASHRAE Standard 52.1 – 1992 and initial resistance at 2.5 m/s face velocity, unless otherwise specified in the Particular Specification. The air filter shall be designed for air velocity of 1.0 to 3.5 m/s. The filter shall operate to 250 Pa final resistance and shall consist of water-resistant media of ultra-fine glass fibers. The media shall be pleated and have suitable separators to maintain the uniform spacing between pleats. The filter assembly shall be of rigid cartridge design, which shall consist of a steel header and cell box to form a supported pleat media pack for various difficult operating conditions. The filter set shall be, unless specified else, of 300 mm thickness disposable extended surface cartridge type. The media shall be water resistant and shall be made of ultra-fine glass fibre formed into thin mate, which shall be supported by corrugated aluminium separators and sturdy enough to operate in a VAV system.

Table C1.3.2 Resistance of Cartridge Filter

<table>
<thead>
<tr>
<th>Average Efficiency Not Less Than</th>
<th>Initial Resistance Not Exceeding</th>
</tr>
</thead>
<tbody>
<tr>
<td>65 %</td>
<td>90 Pa</td>
</tr>
<tr>
<td>85 %</td>
<td>120 Pa</td>
</tr>
<tr>
<td>95 %</td>
<td>150 Pa</td>
</tr>
</tbody>
</table>

C1.4 DISPOSABLE TYPE PANEL FILTER

C1.4.1 Disposable Panel Filter

The air filter shall be disposable glass fibers media panel type. It shall have an average synthetic dust weight arrestance of not less than 80% by ASHRAE Standard 52.1 – 1992, nominal width of 50 mm and an initial resistance not exceeding 65 Pa at 2.5 m/s face velocity, unless otherwise specified in the Particular Specification. The filter shall operate to 250 Pa final resistance.

The glass filter medium shall be supported between two media retainers inside a reinforced cardboard retaining frame. The media retainers shall be suitably designed and fabricated to provide strong support throughout its whole working life, such as combined metal mesh and grilles. The filter element shall be bonded together with a cured resin, with a light adhesive coating, and suitably treated such that the filter medium is not affected by the air moisture, vermin proof and resistant to fungal growth.

C1.4.2 Disposable Pleated Panel Filter
The extended surface pleated filters of similar design to disposal panel filters shall be used when higher air cleaning efficiency and air flow rate are desired. It shall have an average atmospheric dust-spot efficiency of not less than 30% by ASHRAE Standard 52.1 – 1992, nominal width of 50 mm and an initial resistance not exceeding 75 Pa at 2.5 m/s face velocity, unless otherwise specified in the Particular Specification. The filter shall operate to 250 Pa final resistance. The pleated media shall be bonded to the expanded wire mesh to maintain its high efficiency and constant air flow rate.

C1.4.3 Renewable Panel Filter

It shall be used for the heavy dust loading condition when the maintenance cost is the main decision factor. The filter media of usual 50 mm thickness shall be glass or synthetic fibre. The filter media shall be replaceable and is held in position in permanent wire basket, which shall be designed for easy filter element replacement. It shall have an average synthetic dust weight arrestance of not less than 80% by ASHRAE Standard 52.1 – 1992 and an initial resistance not exceeding 65 Pa at 2.5 m/s face velocity, unless otherwise specified in the Particular Specification. The filter shall operate to 250 Pa final resistance.

C1.5 AUTOMATIC FABRIC ROLL FILTER

The filter shall comprise the complete assembly of filter frame, motor, drive, filter blockage sensor and filter media. All sheet metal parts shall be of corrosion resistant galvanized steel construction. The filter media, supplied in roll form and 50 mm thickness, is fed automatically across the face of the filter, while the used dirty media is rewound onto a roll at the other end drum. Each roll shall not be less than 20 meters long for sufficient useful life before replacement is required. The filter shall operate automatically to maintain operating resistance within the range to suit the filter media and the required operating efficiency. The filter shall advance the filter media automatically on the command from a pressure switch, timer, or light-transmission control. The control circuit must operate to ensure uniform feeding of the filter media for constant dirt condition and loading. This shall not need re-calibration if the actual working condition differs from design or if the system is of the variable air volume type. Visual or audible warning to notify the filter media replacement shall be provided. The driving motor shall be automatically switched off when the filter media end is reached and a filter stop alarm shall be generated to alert filter replacement. The controls shall be factory wired and installed electrically to insure fail safe operation. The filter shall be designed and constructed to ensure continuous operation during the routine servicing and maintenance of the filter. The filter media shall be provided with an effective seal to minimize air bypass. A spare roll of filter media shall be provided for each unit.

The initial resistance of the filter shall not exceeding 45 Pa and a mean of 85 Pa under designed operating conditions. The air velocity through the filter media shall not exceed 2.5 m/s. It shall have an average synthetic dust weight arrestance of not less than 80% by ASHRAE Standard 52.1 – 1992, unless otherwise specified in the Particular Specification.
This type of filter shall be constructed of aluminium to withstand washing by water or steam. The filter panel shall be constructed from multiple layers of expanded aluminium mesh or glass, natural or synthetic fibre, with the layers being corrugated or plain and arranged alternately at right angles to one another. Filter media shall be supported on both sides with a rigid and thicker aluminium expanded metal mesh.

Filters shall be 50, 25, 12.5 mm thick with a rolled or extruded aluminium frame. The frame section shall be ribbed for stiffness and its inner edges treated to prevent sharpness and increase strength. Corners shall be mired and riveted where it is necessary. Folding handles shall be applied to the short side of all washable filter panels for easy removal and cleaning. The filter support frame shall be suitable for the installation of either side.

It shall have the following minimum average synthetic dust weight arrestance by ASHRAE Standard 52.1 – 1992 and maximum initial resistance at 2.5 m/s face velocity, unless otherwise specified in the Particular Specification. The filter shall operate to 150, 100 and 75 Pa final resistance for 50, 25 and 12.5 mm thick panels respectively.

Table C1.6 - (1) Resistance of washable panel filter

<table>
<thead>
<tr>
<th>Thickness</th>
<th>Average Arrestance</th>
<th>Initial Resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>50mm</td>
<td>60%</td>
<td>45Pa</td>
</tr>
<tr>
<td>25mm</td>
<td>50%</td>
<td>35Pa</td>
</tr>
<tr>
<td>12.5mm</td>
<td>40%</td>
<td>25Pa</td>
</tr>
</tbody>
</table>

Where coated filtration media is indicated, each layer of expanded aluminium shall be furnished with a thixotropic flame resistant filter coating before assembly into a pack. The adhesive shall have a flash point exceeding 180°C. Performance data for expanded aluminium filter panels oiled with a thixotropic adhesive shall have the following minimum average synthetic dust weight arrestance by ASHRAE Standard 52.1 - 1992, minimum dust hold capacity and maximum initial resistance at 2.5 m/s face velocity, unless otherwise specified in the Particular Specification. The filter shall operate to 150, 100 and 75 Pa final resistance for 50, 25 and 12.5 mm thick panels respectively.

Table C1.6 – (2) Dust hold capacity and resistance of washable panel filters

<table>
<thead>
<tr>
<th>Thickness</th>
<th>Average Arrestance</th>
<th>Dust Hold</th>
<th>Initial Resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>50mm</td>
<td>70%</td>
<td>1600g/m²</td>
<td>50Pa</td>
</tr>
<tr>
<td>25mm</td>
<td>60%</td>
<td>1500g/m²</td>
<td>40Pa</td>
</tr>
<tr>
<td>12.5mm</td>
<td>50%</td>
<td>1100g/m²</td>
<td>30Pa</td>
</tr>
</tbody>
</table>
C1.7 WASHING FACILITIES FOR WASHABLE FILTER

Where washable filters shall be provided, the Contractor shall provide one set of duplicate cleaning tanks (one to wash, one to rinse). These tanks shall be such as to accommodate all sizes of washable filters or if the Contractor wishes several sets of tanks may be provided to accommodate the various filter sizes provided.

The filter cleaning tanks shall be constructed of at least 1 mm thick stainless steel of grade 316 of American Iron Steel Institute minimum and suitably stiffened around the top edges by continuous external turned over inverted ‘u’ sections. The tanks shall be 0.4 m deep. They shall be supplied with 18 mm drain down cock for emptying but shall also have external handles to facilitate turning over to clear sludge.

C1.8 AUTOMATIC VISCOUS FILTER

The filter shall comprise a frame or enclosure, filter plates, motor, drive and fluid tank. There shall be access to the tank containing the fluid to facilitate maintenance and the tools and containers required for the removal of sludge shall be provided. Filter of this type shall have an average synthetic dust weight arrestance of not less than 85% by ASHRAE Standard 52.1 – 1992, unless otherwise specified in the Particular Specification. The design air velocity at the face of the filter shall not exceed 2.5 m/s and operating resistance shall not exceed 125 Pa at the design air volume flow rate. To ensure that there is no carry-over of fluid from freshly wetted surfaces the rate of drive shall be suitably adjusted and set or the filter shall incorporate shielding devices.

C1.9 AUTOMATIC RECLEANABLE HIGH VOLTAGE ELECTROSTATIC FILTER

The automatic recleanable high voltage electrostatic filters shall be able to control odours in the conditioned space and reduce the permanent deposition of contaminants in the space served. It shall have an average atmospheric dust-spot efficiency of not less than 95% by ASHRAE Standard 52.1 – 1992 and an initial resistance not exceeding 120 Pa at design air flow volume rate, unless otherwise specified in the Particular Specification. For kitchen applications, it shall comply with the latest requirements of the Environmental Protection Department on the treatment of gas fired kitchen exhaust air and the unit shall be leakage proof to avoid oil dripping.

The complete set shall consist of an ionizer-collector section power generator, a 50mm aluminium washable panel filters section against over-spray and a motorized washer and adhesive applicator section. All parts shall be factory assembled into a sectioned housing having an overall depth not greater than 1000 mm in direction of airflow. Each section of the galvanized steel housing assembly shall incorporate a pair of hinged, quick opening access doors permitting access for servicing of all internal components; and a watertight, all welded, galvanized steel, drain pan having drain connections. Access doors shall be sealed against leakage by continuous perimeter gaskets of closed cell neoprene.
C1.9.1 Each ionizer-collector section shall be furnished with the required number of one-piece cells of all aluminium construction. Each cell shall be fitted with stainless steel slides for mounting on the tracks, which form an integral component of the side access housing and to facilitate removal of cells for servicing. Cell support framework shall be completely open beneath the ionizer-collector cells to ensure complete drainage of wash water and excess adhesive, minimizing the possibility of short circuits when high voltage power is restored following completion of the wash cycle. Cells shall be designed so that high voltage input terminals and their high volt rated insulators are located completely out of contact with the moving air-stream to avoid build up of dirt which could permit dissipation of high voltage charge and reduce air cleaning efficiency. The high voltage bus bars and contactors shall be inherent to the design of each cell and shall permit cell removal without disconnecting any high voltage wiring. Insulators shall be fully exposed, for ease of cleaning, when cells are removed for service. Cells shall be designed for full-face ionization and shall have completely flat collector plates to prevent buildup of residual, inaccessible dirt accumulations.

C1.9.2 Dual voltage power packs which are designed to provide high voltage to the ionizer circuit and to the plate circuit respectively shall be connected to each ionizer-collector section. The power packs shall be of solid state design, having multiple steps of output voltage adjustment, to include relays of remote indication of primary input and secondary output, shall have “fail-safe” low voltage relays to interrupt power to the ionizer circuit in the event of a malfunction in the plate circuit. High voltage connections between the high voltage output terminals and the bus bar terminals mounted on the ionizer-collector section access door shall be adequately installed. Power pack covers shall each to include primary and secondary neon glow lamps, a circuit breaker, and a manual reset button. Two time delay safety type door interlock switches, with suitable length of safety chain and wiring in series circuit for the power pack, shall be furnished to cut-off the power supply whenever the door is opened.

C1.9.3 Each washer and adhesive applicator section shall incorporate slide-in type, perforated, galvanized steel air distribution baffles and a motor-driven mobile header assembly. The mobile header assembly shall be connected to the inlet water solenoid valve and to the adhesive pump by means of non-snag, expanded PVC hose with a braided polyester exterior protective cover. Rotating washer arms, each equipped with adjustable, multi-directional, 360° washer spray nozzles, shall be driven by reactive force to the high inlet water pressure. The removable brass adhesive nozzles shall be mounted on a separate, fixed, vertical header forming an integral component of the mobile assembly. The filter adhesive shall be cold water soluble and non-flammable. A rotary gear adhesive pump with bronze impeller and sufficient adhesive for at least four reconditioning cycles shall be furnished.

C1.9.4 The washer supply water solenoid valve, the manifold drive motor, and the manifold limit switch shall be pre-wired to an accessible, internally mounted terminal box. The washer control enclosure access door shall incorporate a status light to indicate when the reconditioning cycle is
C1.10 HIGH EFFICIENCY PARTICULATE AIR (HEPA) FILTER

The HEPA filter shall have minimum efficiency of 99.97% in removing small particles of sizes larger than 0.3 micrometer from air by Underwriters Laboratories UL 586 - method of Dioctylphthalate (DOP) Penetration Test. This makes use of a high efficiency glass paper medium and great surface area of medium per cross-sectional area of the filter. It shall reach this rated efficiency when the velocity of the gas passing through the media is 1.5 to 2.5 m/s. Unless otherwise specified in the Particular Specification, a normal HEPA filter of a size 600 mm square with 300 mm thickness, shall have a rated flow of 0.47 m³/s, at a maximum pressure drop of 250 Pa, and about 23 m² of filtering media. The filter shall operate to 600 Pa final resistance.

For clean rooms and clean zones, the HEPA filter shall be selected to meet class 100 of air cleanliness by Federal Standard 209E – Airborne Particulate Cleanliness Classes in Clean Rooms and Clean Zones, unless otherwise specified in the Particular Specification.

Filter shall be constructed from a continuous sheet of the filter medium folded over a separator of aluminium of other approved material to form closely spaced pleats, the whole being sealed into a casing with hard setting synthetic resin cement. This shall enable slower medium velocity and increased efficiency. The media of space filter paper produced wholly from glass microfibres, shall be inert, non-hygroscopic, vermin proof and shall not support bacteria growth. The filter media shall be treated with organic binder materials to provide binder, fungicidal and waterproofing properties.

C1.11 GAS FILTER

The gas filters shall remove contaminating gases from the air by absorption or adsorption. It shall comprise a robust enclosure inserted with module banks which contain evenly disposed chemical media. The complete unit is to be factory assembled and manufactured by the same manufacturer. All joints between the robust enclosure and the module banks shall be effectively sealed to eliminate air bypass and to ensure the optimum removal efficiency. Their supports shall be constructed from steel protected against corrosion and designed to provide mechanical protection to the module banks. The chemical media shall be of uniform thickness packed to ensure that compacting does not occur in use.

The chemical media shall consist of solid sorbents including activated carbons for common volatile organic compounds in indoor air and activated alumina suitably
impregnated with potassium permanganate for formaldehyde and other gaseous contaminants. The combined media shall be able to operate normally at temperature 0 °C to 45 °C and relative humidity 10 to 95 %. It shall be inorganic, non-toxic, non-flammable and shall not support bacterial or fungal growth.

The gas filters shall be selected to give a removal efficiency of not less than 80%, residence time of minimum 0.2 seconds and an initial resistance not exceeding 125 Pa at 1.5m/s face velocity, unless otherwise specified in the Particular Specification. Laboratory analysis of media samples to establish life cycles and remaining life shall be submitted to the Architect for approval.

**C1.12 AUTOMATIC RECLEANABLE FILTER**

Filter media shall be made of reinforced fibre-glass or other suitable synthetic medium mounted on a rotatory tube or a fixed drum. When a preset differential pressure between dirty and clean airsides of the filter is exceeded, the cleaning operation shall be initiated. For the rotatory tube design, the carrier tube shall rotate and suction nozzle with vibrator motor shall move along the filtering surfaces. For the fixed drum design, an air valve installed at the downstream of the filter shall inject compressed air pulse-jet opposite to normal air flow direction. As a result, dirt particles will be pulsed away from the filter and collected in concentrated form inside a collection chamber or an external vacuum cleaner/central vacuum cleaning system connected outside the filter chamber.

Cleaning shall be carried out both during downtimes of the air-conditioning/ventilation system and during plant operation. The medium shall have a filtering efficiency of EU class 9 by Eurovent 4/4 and 4/5. The initial resistance across the whole unit shall not exceed 250 Pa at design air flow volume rate and the final resistance shall not be more than 500 Pa, unless otherwise specified in the Particular Specification.

The internal surface of the filter set shall be absolutely smooth and that of the bottom shall be in trough form with drain so that water can be drained off in case of wet cleaning.

The construction of the service door shall be identical to the casing panel. Non-aging steel-inlaid labyrinth seal shall be integrated into the door leaf. Each door shall be fitted with at least two double lever locks with bolts. Safety cams or chains shall be provided for pressure side doors. All the surfaces of the casing shall be protected against atmospheric corrosion by plastic powder coating.

The whole cleaning cycle shall be actuated and controlled by a sequence controller with basic operation of :-

(a) Reverse blowing by air pulse

(b) Allow few minutes time interval for the dust and other contaminant particles to settle at the collector trap

(c) Operate of the vacuum cleaner/central vacuum cleaning system for a few minutes
(d) Actuate alarm for disposing the contaminant particles when the collecting bag is 80% full

C1.13 FILTER PRESSURE DIFFERENTIAL MEASUREMENT AND INDICATION

A differential pressure gauge of the inclined manometer type shall be provided for each filter bank.

The gauge shall incorporate a graduated scale on which the reading of maximum pressure drop shall occur in not less than 75% of the total scale length.

C1.14 ADDITIONAL REQUIREMENTS (SPARE FILTER MEDIA)

The Contractor shall replace all filters used during testing and commissioning stage and in addition provide the following to the Architect for use by Client’s operation staff during Maintenance Period:

(a) For disposable type filters, one complete set of unused filter cells.

(b) For washable type filters, 20% in number of the filter cells. These shall be new and in good condition. Besides, 10 litre of the approved cleaning detergent per filter installation shall be provided. Regarding filters of viscous type, a drum or drums of fluid amounting to one complete change or 10 litres per filter installation where thixotropic coatings are used shall be provided.

(c) For renewable type filters, one complete set of unused filter media.

(d) For gas filters, one complete set of unused filter cells.

Within one month before Maintenance Period is certified to be complete, all above filter cells/media shall be replaced with new one. In addition, 10 litre of the approved cleaning detergent per washable filter installation shall be provided. Regarding filters of viscous type, a drum or drums of fluid amounting to one complete change or 10 litres per filter installation where thixotropic coatings are used shall be provided.

C1.15 AUTOMATIC RECLEANABLE HEPA FILTER

The whole unit shall be of heavy duty proprietary made air-tight construction. It shall be coated with polyester powder to protect from atmospheric corrosion and to minimize internal friction. By the modular construction, each filter chamber of the unit shall be isolated from the air stream without affecting the operation of the unit while cleaning or replacing the filter cartridges within a particular filter chamber. The filter cartridge shall be designed as drawers by sliding in or pulling out for replacement and repairing services from the front panel and entirely from the clean airside. There shall be no contamination on the filter unit and the environment during the replacement. At the bottom, dust collection containers shall be mounted to each filter chamber by clamps via inter-connecting funnel sections.
Automatic cleaning is conducted by using a counter-current compressed air purge sequence. Filter shall be cleaned periodically by compressed air, which is blown in counter-flow direction to the filter cells from nozzles actuated by pneumatic system from the clean airside. A digital measuring and indication device shall be provided to show the differential pressure of all filter cells in one filter chamber. Cleaning system shall be complete with an electronic self-diagnostic system keeping check with the differential pressure, filter cleaning cycle, replacement period and sudden piercing of the filter medium.

Filter media shall be made of reinforced fibre-glass or other suitable synthetic medium with filtering efficiency of not less than EU class 13 by Eurovent 4/4. The initial resistance across the whole unit shall not exceed 1500 Pa at design air flow volume rate and the final resistance shall not be more than 2400 Pa, unless otherwise specified in the Particular Specification.

C1.16 BIO-OXYGEN GENERATOR (AIR PURIFIER)

The bio-oxygen generator shall be capable of reducing bacteria and airborne contaminants within the area concerned.

All components of the bio-oxygen generator, which are within the air stream, shall comply with the latest requirement of Fire Services Department.

The bio-generator shall have removal efficiency of not less than 95% of Total Bacteria Count (TBC) Test, 95% of cigarette smoke particles and 80% of odours, unless otherwise specified in the Particular Specification. The ozone level generated in the indoor environment shall be less than 0.05 ppm and the background ozone level shall not in excess of the safety standards specified by Occupational Safety and Hygienic Association (OSHA), USA.

Each unit shall be suitable for ductwork mounting and shall consist of electrode tubes and power generator with built in output regulator as described below:

(a) The electrode tube shall consist of electrodes, glass tube and a thread connector at the base of the tube for connection with the tube socket provided at the power generator. Each tube shall be covered by stainless steel mesh and earthed by the grounding leaf spring connected to the power generator. No high voltage part shall be exposed and accessible. All part in contact with air shall be corrosive resistant. The required quantity and output of the electrode tubes for each air handling plant shall follow manufacturer’s recommendation, which shall be sufficient to handle the design air flow rate and the volume of the room being served.

(b) The power generator shall be able to operate on 220V/50 Hz single phase supply. It shall generate appropriate supply to match with the operation requirements of the electrode tubes. It shall be equipped with built-in regulator for output adjustment and shall consist of on/off indicator lamp, overload protection device, tube sockets, control knob for regulator setting and on/off switch.
C1.17 ULTRA-VIOLET STERILIZING LIGHT (UV)

The ultra-violet sterilizing light shall be UL listed and all components within the air stream shall comply with latest requirement of Fire Services Department. It shall be capable of killing mould and other airborne microbial contaminants within the area concerned such as cold, flu and measles viruses, Legionella, tuberculosis and other bacteria, viruses and mould spores.

The sterilizing light shall have one pass bacteria removal efficiency not less than 95% of Total Bacteria Count (TBC) Test, unless otherwise specified in the Particular Specification. The ozone level generated in the indoor environment shall be less than 0.05 ppm and the background ozone level shall not in excess of the safety standards specified by Occupational Safety and Hygienic Association (OSHA), USA.

Each unit shall be suitable for ductwork mounting and shall consist of emitter tube and power generator with built-in output regulator as described below:

(a) The emitter tube shall consist of electrodes, glass tube and a thread connector at the base of the tube for connection with the tube socket provided at the power generator. Each tube is capable of producing broadband UVC waveform in the range around 250-nm mercury spectral line. The required quantity and output of the emitter tubes for each air handling plant shall follow the manufacturer’s recommendation, which shall be sufficient to handle the design air flow rate and the volume of the room being served.

(b) The power generator shall be able to operate on 220V/50 Hz single phase supply. It shall generate appropriate supply to match with the operation requirements of the emitter tubes. It shall be equipped with built-in regulator for output adjustment and shall consist of on/off indicator lamp, overload protection device, tube sockets, control knob for regulator setting and on/off switch.

C1.18 WATER SCRUBBER

Refer to Sub-section A5.5.6.
C2.1 GENERAL

Ductwork shall be off site pre-fabricated according to the requirement as specified in the Particular Specification. The ductwork shall be fabricated from good quality full sized zinc coated hot dipped galvanised flat steel sheet to BS EN 10142, Grade DX51D+Z, coating type Z275 unless otherwise specified in the Particular Specification or the Drawings.

C2.2 OFF SITE PRE-FABRICATION

The development of components for round, oval and rectangular ductwork shall be carried out by a computer software which can produce all development plans from the proposed ductwork layouts including all type of ductwork fittings and accessories. The software shall be able to work out the development plans with utilization factor not less than 94%. Copy of the proposed software details shall be submitted for approval prior to production.

The above utilization factor is based on a ratio of the Standard Size Straight Ductwork: Ductwork Fittings, which is 7 : 3. For standard straight ductwork, the utilization factor is about 100% and that for fittings is about 80%. If the ratio of Ductwork to Fittings is not 7 : 3, the overall utilization factor shall be submitted to the approval of the Architect.

The remaining materials that cannot be used for fabrication of ductwork shall be used for other purpose or as least to be recycled instead of being disposed of as scraps. The software used shall also be linked to the Numerical Control Cutting Machines, such as the Plasma Cutting System for the cutting, development and forming of the required ductwork components and accessories. Copy of the proposed Numerical Control Cutting Machines details shall be submitted for approval prior to production.

Automatic or semi-automatic machines shall be employed for the bending, folding and assembly of ductwork from sheet metal components developed. Proper machines are required for the manufacturing of all ductwork accessories including flanges, stiffeners, splitter dampers, etc in order to enhance quality.

Construction and materials used for ductwork, fittings and accessories shall be inert, non-hygroscopic, vermin and moisture proof, asbestos and CFC free, and shall not support growth of bacteria.

Bends and branch vanes, dampers etc. shall be of the same material as used for the ductwork and/or of heavier gauge, securely mounted.
C2.3 SPECIFICATION AND STANDARDS

Ductwork shall comply with the latest edition of the following HVCA publications with additions or amendments as required by this General Specification and/or elsewhere in the Contract Documents.

(a) DW/144 Specification for sheet metal ductwork (low-medium- and high pressure)

(b) DW/151 Specification for plastics ductwork

(c) DW/191 Guide to good Practice glass fibre ductwork.

Where any part of the installation is not covered by the above, the recommendations of the latest edition of "Low Pressure Ductwork Construction Standards" and "High Pressure Ductwork Construction Standards" issued by the Sheet Metal and Air Conditioning Contractors' National Association (SMACNA) Inc. USA shall be applied.

C2.4 FLEXIBLE DUCTWORK

The flexible ductwork shall have a liner and a cover of tough tear-resistant fabric equal in durability and flexibility to glass fibre fabric. The fabric shall be impregnated and coated with plastics. It shall be reinforced with a bonded galvanised spring of stainless steel or other approved wire helix between the liner and the cover. An outer helix of glass fibre cord or equal shall be bonded to the cover to ensure regular convolutions. Flexible ductwork without a liner may not be used.

In no cases shall material containing asbestos fabric be used.

Alternatively, flexible ductwork shall consist of flexible corrugated metal tubing of stainless steel, aluminium, tin plated steel or aluminium coated steel. The metal surface(s) may be coated with a plastics material.

The leakage from any section of flexible ductwork shall not exceed 1% of the local design air flow rate at the local maximum static pressure.

Flexible ductwork shall be suitable for an operating temperature range of -5° C to 90° C and shall comply with BS 476 Part 5, Rating Class P; Part 6 having an index of performance not exceeding 12 of which not more than 6 should derive from the initial period of test; Part 7 Class 1 (surface of very low flame spread) unless otherwise indicated.

C2.5 DUCTWORK FOR CORROSIVE FUMES

Ductwork used to carry corrosive fumes shall be of non-corrosive material. Where PVC material is used, the minimum thickness shall be 2.4 mm.

Plastic ductwork and all associated moulded or extruded sections, angles and fittings shall be unaffected by the range of substances conveyed and under the
conditions indicated. Unless otherwise indicated, and providing the requirements above can be met, sheet material shall be pressed unplasticised PVC sheet complying with ISO 6453. Where PVC ductwork is thermally insulated or is not readily visible, Type A3 sheet shall be used; elsewhere Type Al shall be used.

Any plastic ductwork system incorporating a heater battery shall be installed such that no part of the system is impaired by the heating effects of the battery or its casing.

Circular ductwork up to 300 mm shall preferably be fabricated from unplasticised PVC pipe complying with ISO 3472 and ISO 3473. Unless otherwise indicated, the colour of sheet and pipe shall be industrial grey. Ductwork shall be constructed (thickness, angles, stiffness etc.) in accordance with Specification DW/151 part 1 uPVC.

Where any part of the installation is not covered by "DW/151", then the recommendations of the latest edition of "Thermoplastic Ductwork (PVC) Construction Manual" issued by the Sheet Metal and Air Conditioning Contractors' National Association (SMACNA), Inc. USA shall apply.

The methods of construction recommended in HVCA Specification DW/151 shall be used, i.e. cemented joints shall be used for circular (pipe) jointing and hot gas/filler rod, welding shall be used for all other fabrication. For circular ductwork constructed from pipe, sufficient angle joints shall be provided to enable the ductwork to be dismantled in the space available. Where so directed by the Architect, all welders shall carry out the test detailed in HVCA Specification DW/151.

The requirements of HVCA Specification DW/151 with regard to expansion joints, ductwork supports, access doors and gaskets shall be met.

Extruded or moulded sections, angles and fittings shall be of the same plastic materials and colour as the sheet or tube.

PVC ductwork shall not be used in situations where it will be subjected to temperatures of 50°C and above. Where heater batteries are required in the system, the PVC ductwork shall be isolated from these by a suitable length of stainless steel ductwork, generally as described for glass fibre ductwork in Sub-section C2.6.

C2.6 GLASS FIBRE DUCTWORK

C2.6.1 General

Where specified in the Particular Specification or the Drawings, glass fibre ductwork made from 25 mm/38 mm thick resin bonded glass fibre in rigid board form may be used. The board shall have an integral external vapour barrier of hard grade, flame retardant, damage-resistant reinforced aluminium foil and an internal smooth, durable acrylic coating that isolates the glass fibre substrate from the air stream and inhibits penetration of the insulation by dirt, dust, micro organisms and other pollutants.
Special attention shall be paid to ensure that the material itself/fabrication/erection of the ductwork does not contribute towards suspected health hazard.

Thickness of the ductwork board to be used shall be selected in accordance with manufacturer's ductwork sizes, static pressure and reinforcement schedule and recommendation.

C2.6.2 Specification and Standards

Specification and Standards for glass fibre ductwork shall comply with the recommendations of the latest edition of HVCA Publication DW/191 Code of Practice for resin bonded glass fibre ductwork, or the "Fibrous glass Ductwork Construction Standards" issued by the Sheet Metal and Air Conditioning Contractors' National Association, Inc. USA. The flexural rigidity rating of the rigid glass fibre board shall be 800E1 (33.7 kg/m²) as defined in the above Standards. Glass fibre ductwork shall meet with the requirements of NFPA 90A and 90B by complying with the requirements of Under-writer’s Laboratories Standard for safety UL 181 for Class 0 ductwork.

Glass fibre ductwork to be used shall resist fungal or bacterial growth when subjected to microbial attack as described in ASTM C665 and Standard Practices ASTM G21 (fungus test) and G22 (bacteria test).

Glass fibre ductwork shall be easily cleanable using methods and equipment described in North American Insulation Manufacturers Association (NAIMA) Publication AH-122, Cleaning Fibrous Glass Insulated Ductwork Systems.

C2.6.3 Mounting of Fittings

Where the following items are installed in a ductwork, a suitably sized section of galvanised sheet ductwork shall be installed complete with independent supports and insulation:

(a) Electric or hot water etc. ductwork heaters and access panels
(b) Volume control dampers
(c) Fire dampers and access panel
(d) Fan and access panel

C2.6.5 Mountings of Instruments

All control/metering probes, etc. which require mounting in fibre glass ductwork shall be adequately supported by a sheet metal panel securely fixed to the internal face of the ductwork. The Contractor shall fix a removable insulated cover over the complete probe to ensure condensation will not occur on any exposed metal surfaces.

C2.6.5 Special Tools and Manufacturers Fabrication Instructions

The construction and installation including all cutting tools employed to fabricate the ductwork shall be strictly in accordance with the
recommendations of the fibre glass ductwork manufacturers instructions issued for the correct installation of their product. Fabrication and installation by any method other than that endorsed by the fibre glass ductwork manufacturer may be rejected by the Architect.

C2.7 PHENOLIC FOAM DUCTBOARD DUCTWORK

C2.7.1 General - Where specified in the Particular Specification or the Drawings, pre-insulated ductwork made from 20 mm thick rigid closed cell phenolic foam in rigid board form may be used.

C2.7.2 The ductwork material shall be covered with a layer of vapour barrier on both board facing. The vapour barrier shall be of minimum 20 micron thick aluminium foil. The circumferential and longitudinal seams of the vapour barrier foils shall be sealed with self-adhesive foil tape as specified in Sub-section C11.4.3.

C2.7.3 All material shall have a class 'O' fire rating and certificate from Fire Services Department. Details refer to Sub-section C11.2.1. Low smoke emission shall comply with BS 5111 Part 1 and shall be CFC free.

C2.7.4 The flange system for the phenolic foam ductwork shall be designed to eliminate the effect of "Cold Bridge" and for the purpose of sealing, the flanges shall be coated with fire resistant gaskets and securely mounted with sufficient bolts, nuts and clips. An established joining system shall be employed in connecting the ductwork and accessories such as air outlets and dampers. The joining system shall be approved by the Architect.

C2.7.5 Where the following items are installed in the ductwork, they shall be adequately supported by a sheet metal panel securely fixed to the internal face of the ductwork with due consideration to ensure that condensation will not occur on any exposed metal surface :-

- Ductwork heaters
- Volume control dampers
- Fire dampers
- Fans & access panels

C2.7.6 The construction and installation including all cutting tools, adhesives, flange system shall be strictly in accordance with the recommendations of the phenolic foam ductboard manufacturer's instruction.

C2.8 DAMPERS - GENERAL

The respective functions, types and general constructional requirements of dampers shall be in accordance with the HVCA ductwork specification DW/144 unless otherwise indicated, sufficient dampers shall be provided to regulate and balance the system. Dampers on grilles or diffusers shall be used for fine control only.
All dampers shall be of flanged type for connection to ductwork and shall be sufficiently rigid to prevent fluttering. Air leakage rate for dampers shall be tested according to EN 1751 Section 3 when the damper is in the closed position. For dampers installed for shut-off purpose, the maximum air leakage rate shall be tested according to EN 1751 Section 4.

Air volume control dampers shall be of the aerofoil, double skin, opposed blade type with low pressure drop and noise regeneration characteristics. Damper blades in rectangular ductwork shall not exceed 225 mm in width and 1500 mm in length. Blades shall be of hollow section constructed from the same material of the ductwork or of stainless steel encapsulating an internal double contoured steel longitudinal reinforcing bar, mounted on square section steel spindles. Bearings shall be of nylon material and the units shall be of low-leakage design by incorporation of synthetic trailing edge seals and a peripheral gasket which shall be tested according to BS 476 Part 6 and 7 and shall be approved by the Fire Services Department. All manually and automatically operated dampers shall include a means for indicating externally the position of the blades. Manual dampers shall include a device for positioning and locking the damper blades. The positions of all dampers 'as-set' after final regulation shall be indelibly marked at the adjusting device.

Each air volume control damper in the ductwork shall be fitted with a non-corrodible label stating the actual air flow in m$^3$/s when in the fully open position, its overall cross sectional area, and the degree to which the damper has been closed in order to achieve the design or actual air flow.

Unless otherwise indicated, quadrants and operating handles shall be of die-cast aluminium or other material approved by the Architect with the words 'OPEN' and 'SHUT' cast on the quadrant.

Quadrants shall be securely fixed and the damper spindles shall be closely fitted in the quadrant hubs to prevent any damper movement when the damper levers are locked.

Access openings with readily removable air sealed covers shall be provided adjacent to all dampers. Subject to limitations of ductwork size the dimensions of access openings shall not be less than 300 mm x 300 mm and they shall be located so as to afford easy access for inspection and maintenance.

**C2.9 BUTTERFLY, BIFURCATING AND MULTILEAF DAMPERS**

Butterfly dampers shall each consist of two plates, edge seamed, of at least the same thickness as the material from which the associated ductwork is made, and rigidly fixed to each side of a mild steel operating spindle, the ends of which shall be turned and housed in non-ferrous bearings.

Bifurcating dampers shall be of 2 mm thick sheet for sizes up to 450 mm square, for larger sizes the thickness shall be as specified. The damper blades shall be rigidly fixed to square section mild steel spindles, the ends of which shall be turned and housed in non-ferrous bearings.

Each leaf of a multileaf damper shall consist of two plates of material of the same thickness as the associated ductwork and rigidly fixed to each side of an operation...
spindle, the ends of which shall be housed in brass, nylon, oil impregnated sintered metal, PTEE impregnated or ball bearings. The ends of the spindles shall be linked so that one movement of the operating handle shall move each leaf for an equal amount. The mechanism shall be located outside the air stream.

For system static pressure below 1000 Pa or ductwork velocity below 12 m/s, blade of at least 50 mm wide shall be used. For static pressure at or above 1000 Pa, at least 100 mm wide blade shall be used. Central blade reinforcement bar shall be provided for damper span longer than 1500 mm. Single module of a damper shall not exceed 2000 mm width and 1000 mm height.

Alternatively, multileaf damper blades may be of a single plate, at least 1.6 mm thick and suitably stiffened, and the blade linkages may be within the ductwork. These dampers shall have bearings and inspection doors as specified in Sub-section C2.8.

**C2.10 SELF-CLOSING (NON-RETURN) DAMPERS**

Self-closing dampers shall present a minimum resistance to air flow under running conditions and take up a stable position in operation. Maximum resistance shall be presented under reverse air flow conditions such that they will be forced to close and remain so. Resilient strips or other purpose made devices shall be provided to prevent the damper from rattling and as an aid to air sealing under reverse flow conditions.

Blades shall be rigidly constructed of steel or aluminium sheet of not less than 0.8 mm (22 gauge) and shall be free of all buckles. Blades of less than 300 mm in height shall be fitted with a 3 mm (10 gauge) bright steel spindle at each end. Blades of 300 mm and over in height shall be fitted with a 8 mm bright steel spindle at each end. Spindles shall be carried by sealed ball bearings. Bearing shall be accessible for cleaning and lubrication and shall be mounted in a rigid galvanized steel frame. The maximum length of each blade without a central bearing shall be 1000 mm.

**C2.11 FIRE, SMOKE AND COMBINED FIRE SMOKE STOP DAMPERS**

**C2.11.1 Fire and Smoke Stop Dampers**

Fire or Smoke dampers shall be provided in ductwork in the following locations:-

(a) Wherever a ductwork passes through a floor slab or a fire resisting wall which is expressly built for the purpose of preventing the spread of fire.

(b) Other locations where requirements of compartmentalisation are stipulated in the Code of Practice for FRC under the latest edition of the Building Ordinance of Hong Kong.

(c) Other locations as required by the Particular Specification and the Drawings.
Fire or Smoke dampers used singly or in combination shall have an overall fire rating not less than that indicated and certainly not less than that for the wall or floor slab in which they are situated.

In all cases, evidence of fire rating in accordance with ISO 10294 Classification E (BS 476 part 8) or NFPA 90 A with 2-hour UL fire damper label shall be provided by an independent testing organisation approved by the Architect. All Fire or Smoke dampers shall also be approved by the Fire Services Department.

Fire or Smoke damper blades of proprietary made shall be constructed to the approved and recognised testing authority and posses a rating equivalent to the fire resistance of the structure it protects.

Local made fire or smoke damper blades shall comply with the requirements of the Circular Letters issued by Fire Services Department and the Building Ordinance of HKSAR. These blades shall be housed in a corrosion resistant casing constructed to avoid distortion due to stress in fire conditions. Stainless steel spring tempered flexible gasket shall be inserted between the blade and the casing for elimination of closing friction and retardation of smoke. Provision shall be made to accommodate expansion of the damper blades within the casing in fire conditions to prevent jamming and to retard the spread of smoke. A Fire or Smoke damper installation frame supplied by the same manufacturer shall also incorporate provision for expansion within the surrounding structure together with masking flange for building into the structure.

Fire or Smoke damper assemblies for installations in corrosive environments shall be fabricated from suitable materials resistant to the corrosive substances and environments indicated. Alternatively, the material may be coated with a protective finish to produce the same effect.

Power fail-safe remote electromagnet release shall be provided to explosion hazardous areas. The electromagnet shall normally not consume more than 10mA by 220V AC supply or 120mA by 24V AC/DC supply. The Contractor shall be responsible for the power fail-safe fire dampers to the fire control relay at the fire service control panel.

Each Fire or Smoke damper casing shall be air tight, continuously welded and clearly marked with a permanent indication of the direction of air flow and the side at which the access/maintenance opening is located.

The folded continuous interlocked blade type of damper may be used for vertical or horizontal ductwork applications. The closing force for these type of dampers shall be provided by stainless steel spring or springs. An automatic locking device shall be provided to ensure that the blades are held in the closed position after release.

Spring actuated pivoted single-bladed or multi-bladed dampers may be used for vertical or horizontal ductwork applications.
Multi-bladed dampers shall be provided with a means to ensure that all the blades close simultaneously.

Gravity operated multi-bladed fire dampers shall not be used in vertical ductwork.

Gravity operated single bladed dampers may be used for horizontal ductwork provided means are incorporated which ensure reliable and positive closure when operating in maximum air flow rate conditions.

Locally fabricated gravity fire dampers shall be provided with a coaming or casing of the same material and shall be physically bolted to the structure through which the ductwork penetrates.

Fire or Smoke dampers shall be rated in accordance with the fire rating of the wall, ceiling or floor etc. as shown in the drawings and the Particular Specification, to the requirements of the Fire Services Department and acceptable by the Architect.

For locally fabricated fire dampers, the thickness of metal for the dampers shall comply with the Circular Letters issued by Fire Services Department and the Building Ordinance of HKSAR.

Where gravity acting off-centre pivoted dampers incorporate spindle bearings long term corrosion effects shall be minimised by the choice of suitable materials. Bearings shall be sealed or capped to exclude dirt and dust. Damper blades shall close to comply with the stability and integrity requirements of ISO 10294 Classification E (BS 476 Part 8).

For high velocity air systems, fire/smoke dampers shall provide 100% free area when damper blades are in the open position to give minimum interference to the air flow.

Unless otherwise indicated, each Fire or Smoke damper shall be held in the open position by a corrosion resistant retaining device incorporating a fusible element which shall operate at a temperature of 69 °C, unless otherwise indicated.

Fire or Smoke dampers shall be located in a position and be of a type which could facilitate periodic one handed manual release and re-setting for test purpose.

Proprietary access doors shall be installed adjacent to each Fire or Smoke damper and, in the case of conditioned air or kitchen exhaust ductwork, the access doors shall be encapsulated and pre-insulated.

C2.11.2 Combined Fire and Smoke Stop Dampers

Combined fire and smoke stop dampers shall be tested to ISO 10294 classification ES and approved by the Fire Services Department.

The dampers shall be of stainless steel, aerofoil bladed construction with the blades held in stainless steel bearings and framed in stainless steel
spring tempered flexible gasket. The blades shall have trailing edges forming an interlocking metal to metal seal when the blades are closed, providing tight, low leakage closure of the air path and maximum impedance to the passage of smoke and products of combustion from either flow direction.

The blades shall be driven by externally mounted and totally enclosed stainless steel gearbox and drive mechanism providing accurate blade control with minimum torque and without accumulative backlash.

The damper casing shall be of double-skin galvanized steel construction with continuously welded corners and integral spigot connections. The dampers shall be supplied complete with the manufacturer-installed frames.

Each damper shall have an externally replaceable combination thermal actuator and fusible link completely exposed to the air stream.

In addition to the thermal actuation/fusible link, the damper shall be normally held by electromagnetic device with power rating of not more than 3.5W. The damper shall be released to the closed, or fail-safe position within 1 second by an independent closure spring on loss of power supply, either by genuine power failure or by the zone fire signal actuated by the smoke detection system.

The damper shall be automatically reset on resumption of power supply by built-in motor of 220V AC or 24V AC/DC.

The whole control mechanism and actuation shall be of the same manufacturer and mounted inside a totally enclosed casing for protection against airborne contamination and to ensure unique reliability.

For smoke extraction at 250°C for 1 hour application, damper control actuator shall be totally shielded by a proprietary thermal insulation jacket. The whole damper assembly shall have undergone a high temperature operation test followed by a leakage test at 1500Pa differential pressure and ultimately approved by the Fire Services Department.

Leakage rate shall be tested in accordance with UL555S.

Fire rating shall be to BS 476 and the whole damper assembly shall have undergone a temperature exposure test by an independent laboratory in accordance with the temperature and duration as indicated in BS 476. Test report shall be submitted to the Architect for reference.

C2.12 MOTORIZED SHUT-OFF DAMPERS

Motorized shut-off dampers shall be similar to fire/smoke dampers and shall be open or close by motorized mechanism. Each of the damper shall be in “Open” position normally, but shall be closed in case of fire. The motorized mechanism
shall be actuated by associated automatic fire detectors. Air leakage rate for motorized shut-off dampers shall be tested according to EN 1751 Section 4.

C2.13 TERMINAL DAMPERS

Grilles and air diffusers with rectangular neck connections shall be provided with an opposed blade damper, screwed or riveted to the neck connection and designed specially to facilitate final balancing of the system.

Damper frames, blades and operating mechanism shall be constructed from an aluminium alloy or, alternatively, formed mild steel suitably finished to give protection to the material during the design working life.

Blades shall be made of solid section material and shall be firmly held in position by a spring steel retaining mechanism. The blade setting mechanism shall be accessible through the grille or diffuser blades and shall be suitable for operation with an “Allen” key. Where dampers are visible through the grille or diffuser they shall be finished with a matt black paint.

C2.14 ACCESS DOORS AND PANELS TO DUCTWORK, CABINETS, COLD STORES

Unless otherwise indicated, locally fabricated Access Doors or Panels shall be constructed of marine plywood on seasoned teakwood frames in accordance with the Architect's issued Standard Details, suitably insulated where necessary and finished with at least three coats of shellac, lacquered and polished.

The insulation in the door shall be equal to that of the ductwork or cabinet into which it is installed. When closed, the door shall be effectively vapour sealed.

On doors through which a man can pass, the opening handle must also be operable from the inside of the door.

Access doors and panels on factory made equipment shall be approved by the Architect.

All fittings and screws shall be made of brass.

Access doors or panels to ductwork heaters shall be constructed in accordance with the Architect's issued Standard Details for ductwork heaters.

Access doors shall be of proprietary manufacture, double-skin, 25 mm sandwich G.I. construction with fibreglass or CFC-free foam insulation infill. Access doors shall be of lift off type having a minimum of 4 cam-lock action retaining locks for fixing to ductwork frame. Gaskets shall conform to DW/144 & 143. Access doors shall be supplied and fitted with retaining chain tied back to the frame. Multiple screw fixings shall not be allowed.
C2.15 DUCTWORK FLANGES

All rectangular ductwork shall be flange joints. Flanges shall be of a proprietary type, tested and certified for air leakage and deflection to DW/144. Certificates must be submitted during the equipment submission period.

The proprietary ductwork flanges shall be roll-formed from zinc coated hot-dipped galvanised sheet metal to BS EN10142 Grade DX51D+Z, coating type ZF180. Flanges shall be constructed with prefabricated flange profile consisting of manufacturer provided integral sealant with corner joints inserted into the end of the flange profiles and the whole frame shall be firmly secured including the corner component. The already established ductwork flange shall be fastened into the associated ductwork with spot welding. Gaskets strip shall comply with BS 476 Part 7, Class 1 and ductwork sealant to BS 476 Part 7, Class 2 shall be applied at the flange joints and corner joints respectively to ensure maximum leakage-proof. All sealant used shall be fire proof and vermin proof, non-toxic and acceptable to the Fire Services Department.

Sealant and gaskets shall be provided by the flange manufacturer.

C2.16 DUCTWORK CLEANING POINTS

The ductwork cleaning point shall generally be of a type consisting of a 50 mm diameter metal flange with a 20 mm diameter hole closed with an air-tight screwed plug through which inspection, cleaning and disinfection of the ductwork can be carried out.

The ductwork cleaning point shall be of proprietary product, so constructed and installed that no cold bridge which cause condensation will occur.

C2.17 TEST HOLES

Test holes shall be provided wherever necessary for effective balancing and testing, whether these provisions are shown in the Drawings or not. Test holes shall be of 25 mm diameter and fitted with an effective removable sealed cap. Test points shall be provided for all dampers and items of equipment to enable fan duties and items to be assessed and for the commissioning of the system.

C2.18 TRANSFER DUCTWORK

The internal lining material shall be in accordance with Sub-section C8.7 of this General Specification.
SECTION C3
AIR HANDLING AND TREATMENT EQUIPMENT

C3.1 GENERAL

C3.1.1 Fans shall comply with quality standard ISO9001/9002 and be 'type' tested in accordance with the requirements of BS 848 (or related content of ISO5801, 5136 & 13351). The Contractor shall submit the make and type of each fan together with the 'type' test certificate for the Architect's approval. The origin of the fan shall be from the country where the 'type' test was conducted.

C3.1.2 All fans should be constructed to a fully developed design and shall be capable of withstanding the pressures and stresses developed during continuous operation at the selected duty. Additionally, all belt driven fans shall be capable of running continuously at 10% in excess of the selected duty speed.

C3.1.3 Fans shall be selected to give the air volume flow rates and sound power levels specified in the Contract Documents. Fan performance curves giving values of sound power levels and fan efficiency at the selected duty shall be provided with the tender. Values of resistance to airflow of items of equipment, ductwork and/or the total distribution system indicated in the Contract Documents are based on basic design assumptions, the Contractor shall verify these values based on the actual equipment offered and installed and to provide fans capable of delivering the required air volume when operating against the actual total installed system resistance.

C3.1.4 Fan Construction

(a) Centrifugal fans having dimensions over 1000 mm in any direction shall have split casing for easy removal and repair.

(b) The shaft and impeller assembly of all centrifugal, axial flow and mixed flow fans shall be statically and dynamically balanced. All propeller fans shall be statically and dynamically balanced. Limits of vibration severity shall be in accordance with BS 4675 Part 1.

(c) Fan shall be equipped with self-aligning bearings suitable for the installed altitude of the fan. They shall be of the grease/oil ball and/or roller type or alternatively oil lubricated sleeve type. All bearing housings shall be precisely located in position and arranged so that bearings may be replaced without the need for realignment. Bearing housings shall be protected against the ingress of dust and, where fitted with greasing points, they shall be designed to prevent damage from over-greasing. For grease lubricated systems the bearings shall be provided with grease of the
amount and quality as recommended by the bearing manufacturer. For oil lubricated systems the housings shall provide an adequate reservoir of oil and shall include a filling plug and be oil tight and dust proof. Systems other than total loss types shall include an accessible drain plug. All bearing lubricators shall be located to facilitate maintenance. Extended lubricators outside the fan casing shall only be required if sealed for life bearings are not incorporated.

C3.1.5 Fan and motor for smoke extraction and staircase pressurization ventilation system shall be suitable for smoke handling of 250ºC and above, and all control and power wiring shall be of the MICS type. The latest requirements specified by Fire Services Department shall also be complied.

C3.2 AIR HANDLING UNITS (AHUs)

C3.2.1 General

Each type of equipment offered shall be the product of a manufacturer who has made similar product for a period of at least five years. Each equipment for a project shall have all its parts and components supplied from one single manufacturer.

Individual components forming part of the air handling unit shall, in addition to this section, comply with the appropriate sections contained elsewhere in this General Specification. Air handling unit shall comply with quality standard ISO9001/9002 and be 'type' tested. The Contractor shall submit information on the make and type of each unit together with the 'type' test certificate for the Architect's approval. The fan, motor and the driving system shall be proprietary products from the country of origin where the 'type' test was conducted.

C3.2.2 Construction

AHU assemblies shall be of rigid double skin fully modular construction with each section having matching cross sectional dimensions and same construction type. All individual components and sections shall be assembled using proprietary and approved fastening techniques. Locking devices shall be used with all fastenings which are subject to vibration. Air leakage of the assembled unit shall be to HVCA Standard DW/144 Class B or EN1886:1998 Class B.

Each module shall be supported by rigid galvanized steel post frame or extruded aluminium alloy framework or other composite material frame as specified with thermal break design and flush mounted with dismountable sandwich panel, corrosion resistant treated and strengthened where necessary to prevent minimum deflection and drumming even at 2500 Pa differential pressure. The post frame and corner pieces shall be fixed together to provide strength equal to welding.
The removal of the side panel shall not affect the structural integrity of the unit.

The construction of the unit shall be such that the inner surface of the unit is thermally broken from the outside surface without any cold bridge formed. The frame member and corner piece shall be internally insulated with close cell elastomeric insulation or other approved insulation. The double skin or sandwich panel shall be no less than 25 mm thick with injected expanded polyurethane foam insulation or other approved insulation encapsulated by epoxy or approved coated finishing solid sheet steel. Non-hydroscopic sealing shall be provided between the panel and the framework. The width of the frame member & corner piece shall be the same as the thickness of the panel.

The whole construction shall be hygienically designed and the internal surface shall be smooth to avoid any framework protrusion inside the casing.

Casing material shall not be less than the thickness as shown in Table C3.2.2 unless otherwise specified in the Particular Specification and methods of strengthening and fastening shall ensure that air handling assemblies are not less but preferably more rigid in operation than the distribution duct to which they connect. Other material thickness is acceptable provided that the Contractor can provide detailed calculation demonstrating that the casing and framework construction is more rigid than the specified thickness.

<table>
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<tr>
<th>Component</th>
<th>Minimum material thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel framework</td>
<td>2.0</td>
</tr>
<tr>
<td>Cooling coil casing</td>
<td>1.6</td>
</tr>
<tr>
<td>Panel for polyurethane insulation (each face)</td>
<td>0.8</td>
</tr>
<tr>
<td>Other</td>
<td>1.2</td>
</tr>
</tbody>
</table>

All metal surfaces must be properly treated and suitably painted. Galvanized sheet metal finish is not acceptable. External wall shall be galvanised steel, chemically treated, pre-coated with primer and plastisol topcoat.

C3.2.3 Fan

Fan/motor assembly shall be mounted on a common framework inside the fan section. The fan discharge shall be isolated from the casing by a flexible connection. Fan shall be driven by at least two-belt arrangement. Selection of fan and motor shall be at their peak operating efficiency. Fan motor shall be supplied and installed by the AHU manufacturer unless otherwise specified.

C3.2.4 Access Doors
These shall generally be as detailed for acoustically treated doors described in the relevant content of Section C8. They shall also meet with the insulation requirements stated in the relevant content of Section B11 & C11. The access doors shall be 600 mm wide and vertically sized for the full height of the unit or 600 mm wide by 1500 mm high where the unit height exceeds 1500 mm. Quick access doors shall be provided for filter section, coil section, transfer section, humidifying section, damper section, etc. Heavy duty double hinges and two quick release fasteners shall be provided for all quick access doors.

Where return or fresh air ductwork connects to air handling units, access to the filters shall be through side access panels at the filter chambers.

C3.2.5 Component Separation

Sections of packaged units shall be arranged with adequate separation to avoid re-evaporation of condensate from the cooler by any heating coils installed to generally promote even air distribution across the face of all components and to allow better access for maintenance.

C3.2.6 Anti-Corrosion Treatment

Where units incorporate humidifying plant and/or cooler batteries, the internal surfaces of the units liable to be affected by moisture shall be of non-ferrous materials or galvanized mild steel sheet. The G.I. metal sheets shall be protected by at least two coats of anti-corrosion epoxy resin paint, colourcoat, or other approved finish applied in the factory. Field painting after the installation is not accepted.

Note: Colourcoat, a plastic coated steel panel, has a life expectancy in excess of 40 years in normal environments. The coating is tough and scratch resistance and is applied over a PRIMER and GALVATITE substrates for even better corrosion resistance.

C3.2.7 Thermal and Acoustic Insulation

The unit shall be cold bridge free without sweating even under ambient conditions of 35°C and 98% RH. Thermal insulation shall be expanded polyurethane foam or other approved material having a thermal conductivity not greater than 0.02 W/m°C rated at the operating temperature. The insulation shall provide a high degree of noise attenuation. Insertion loss through the panels shall be sufficient to achieve a 25 dB and 27 dB reduction at 63 Hz and 125 Hz octave bands respectively.

Insulation of sufficient thickness not less than 25 mm shall be selected and applied to prevent surface condensation at design conditions and to minimize noise attenuation. Thermal insulation shall be securely fixed to or built into all sections of plant and equipment handling heated or cooled air. Where appropriate, a vapour barrier shall also be provided. Thermal and/or acoustic insulation characteristics and fixings shall be in accordance with Sections B11 & C11 and B8 & C8.
Particular care shall be taken to ensure surface protection of internal insulation in areas where free moisture may be present and to avoid damage in sections having walk-in access. Adequate lighting complete with door operated switch equipped at the factory shall be provided for AHUs with handling capacity greater than 5 m³/s.

C3.2.8 Air Filters

The filter section shall be provided by the air handling unit manufacturer or specialist manufacturer of filter holding frame approved by the Architect. The construction of filter section shall comply with the requirements of Sub-section C3.2.2 and shall ensure that there will not be bypass of un-filtered air. The filter section consisting of the filter elements and the filter fixing frames must have a positive means of sealing off the unfiltered air by-passing the filter elements.

Intermediate bag filter or HEPA filter with 50 mm thick permanent washable pre-filter shall be provided. HEPA filter and bag filter cartridges shall be mounted on non-corrosive aluminium or stainless steel tightness proof holding frame for side service or front release depending on the restriction of access. Neoprene gaskets shall be provided along the contact surfaces of the filter element and the holding frame. Filter cartridges shall be clamped against the slide rails with spring type clamping devices. The spring clamping devices shall be released by a single acting pneumatic cylinder for insertion or removal of the filter elements.

A test groove shall be provided on the filter seat of the holding frame of each filter element with a testing port for the connection to a portable tightness testing device provided by the Contractor. The portable tightness testing device shall comprise the followings:

(a) A volumetric flow meter to measure leakage flow rate from 0.01 to 0.15 l/min.

(b) A volumetric flow meter to measure leakage flow rate from 0.15 to 1.5 l/min.

(c) Hand-pump.

(d) Connection for external compressed air system (max. 1.1 bar).

(e) Pressure gauge for hand-pump and external system.

(f) Connection tube linking the testing device and the tightness proof frame.

(g) Throttle valve.
Air by-pass preventive devices and testing facilities other than the above shall be submitted for the Architect’s approval.

A sample of the whole air-tight filter frame shall be delivered to site for the inspection and approval by the Architect prior to bulk manufacturing of AHU (50 nos. or more) or otherwise as specified in the Particular Specification.

The filter shall not be located any closer than 500 mm to electric heaters or water heating battery.

The following air filters shall be provided in accordance with the application of the air handling system:

Table C3.2.8(g) – (1) Pre-filter

<table>
<thead>
<tr>
<th>Application</th>
<th>Arrestance % (A) BS EN779</th>
</tr>
</thead>
<tbody>
<tr>
<td>For use where grease or moisture is prevalent</td>
<td>80 &gt; A ≥ 65</td>
</tr>
<tr>
<td>General ventilation system suitable for sport halls, swimming pools, ice rinks, garages, plant rooms, laundries</td>
<td>90 &gt; A ≥ 80</td>
</tr>
<tr>
<td>General ventilation system suitable for office, auditoria, law courts, TV studios, hall and lobby, kitchens, station concourses, etc.</td>
<td>A ≥ 90</td>
</tr>
</tbody>
</table>

Table C3.2.8(g) – (2) Intermediate filters

<table>
<thead>
<tr>
<th>Application</th>
<th>Efficiency % (E) BS3928 (or EN779)</th>
</tr>
</thead>
<tbody>
<tr>
<td>General ventilation system for church, hotel</td>
<td>80 &gt; E ≥ 60</td>
</tr>
<tr>
<td>General ventilation systems suitable for foyer, dressing room, bar/lounge, restaurant, library, office, building society, department store, supermarket, airport</td>
<td>90 &gt; E ≥ 80</td>
</tr>
<tr>
<td>General ventilation system suitable for museum/art gallery,</td>
<td>95 &gt; E ≥ 90</td>
</tr>
<tr>
<td>Application</td>
<td>Efficiency % (E) BS3928 (or EUROVENT 4/4 &amp; 4/5)</td>
</tr>
<tr>
<td>-------------------------------------------------</td>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td>Special ventilation systems for hospital, clean room, research laboratory</td>
<td>99.999 &gt; E ≥ 95</td>
</tr>
</tbody>
</table>

Table C3.2.8(g) – (3) High efficiency and HEPA filter

The quantity of spare filter shall refer to Sub-section C1.14.

C3.2.9 Air Cooling Coils

(a) General

Cooling coils shall be mounted on non-corrosive aluminium slide rails. Coil sections shall be arranged to provide removal of coils from the access side of the section. Air cooler casings shall be of galvanized sheet steel not less than 1.60 mm thick with flanged ends drilled and corrosion treated to receive counter flanges on connecting ductwork or other associated equipment. The bottom of casings shall be made in the form of a watertight drip tray from American Iron Steel Institute 316 stainless steel after manufacture. Water shall not be carried over from a cooling coil into the remainder of the system and an eliminator section shall be provided, wherever necessary or indicated. The drip tray serving the cooling coil shall be extended or a separate tray be provided to collect water from the eliminator. Drip trays shall be sloped towards a bottom drain connection and pipework shall be installed from each connection to the nearest sump or gully. The drain tray shall be accessible for cleaning without the coil having to be removed. The drain pipework shall include a water seal of adequate depth to prevent entry or exit of air to or from the system. A separate drip tray shall be provided for each 1.2 m depth of coil. On stacked coil, intermediate drain troughs shall be provided. All drip trays shall be adequately insulated with durable, non-smell and non-peeling under cooling/heating and air flow design conditions. Sealing devices shall be provided at tops and bottoms of coils to minimize air by-pass and water carry-over.
Cooling coils shall utilise the full unit available cross sectional area. Cooling coils shall be constructed from one of the following combinations:

(i) Copper tubes expanded into aluminium fins.
(ii) Copper tubes expanded into copper fins.
(iii) Tinned copper tubes expanded into aluminium fins.
(iv) Copper tubes expanded into tinned copper fins.
(v) Copper tubes expanded into plastic coated aluminium fins.

Tube thickness shall not be less than 0.45 mm. Fin thickness shall not be less than 0.24 mm with suitable fin spacing.

(b) The resistance to airflow through a cooler battery shall not exceed 125 Pa taking into account the wet air condition. The face velocity of airflow shall not exceed 2.5 m/s.

(c) Air cooling coils shall be supported such that their weight is not transmitted to ductwork and they can be removed without disturbing adjacent ductwork. Access doors with air seals shall be provided on both the upstream and downstream of the cooling coils and shall be sized for the full height of the connecting ductwork but need not exceed 1800 mm.

(d) Before leaving the manufacturer’s works cooling coils shall be proof tested at 26 bar and leak tested at 17 bar.

(e) The number of rows of coil for primary air handling unit shall not less than eight rows and for other air handling units shall not less than six rows. Details performance calculation with safety margin shall be submitted for Architect’s approval for coil row less than the above specified.

C3.2.10 Chiller Water Connections to Cooling Coils

The flow and return connections and headers shall be made of heavy gauge seamless flanged copper tube. Provision shall be made for thermal expansion of the tubes, for effective venting of the coils and their connections and for the draining of the headers and tubes.

Coil connections shall be arranged so as to enable same side connections to the flow and return pipework, and to have the supply and return connections to headers to give counter flow of air and water. Equal flow of water shall be through all the tubes in the coils.

(a) Up to and including 50 mm bore connections may be made using ground-in spherical seated unions. Pipework of 65 mm bore and above shall be connected using flanged joints. Isolating valves shall be provided on flow and return connections and arranged so as to facilitate easy removal of the cooler.
(b) For rigidity, the short pipe length connecting the copper coil header and the external G.I. or black steel pipe work shall be stainless steel pipe having the same bore size as the copper header.

C3.2.11 Hot Water and Steam Air Heating Coils

(a) General

Casings shall be of galvanized sheet steel not less than 1.60 mm thick with angle framing at each end drilled ready to receive the counter flanges on the connecting ductwork. Heaters shall be supported so that their weight is not transmitted to ductwork and so that they can be removed without disturbing adjacent ductwork. Access doors with air seals shall be provided on both the upstream and the downstream sides of the heating coils and shall be sized for the full height of the connecting ductwork of AHU section but need not exceed 1800 mm.

(b) The heating coil shall be of one of the following types as indicated:

(i) Copper tubes with non-ferrous fins, fitted into copper or bronze headers.
(ii) Copper tubes with non-ferrous fins, fitted into steel or cast iron headers.
(iii) Mild steel tubes with mild steel fins, fitted into steel headers, the whole protected against corrosion.

c) The performance of heating coils shall be as indicated and the method of testing for rating of the coils shall be in accordance with BS 5141 Part 2.

d) For C3.2.11(b)(i) and (ii) above, the copper tubes shall comply with the test requirements as specified in BS EN1057, and the secondary extended heating surface shall be of either aluminium or copper as indicated. For C3.2.11(b)(iii) above, the steel tubes shall comply with the requirements of BS 1387 (or ISO65). The secondary heating surfaces shall in all cases be in continuous mechanical contact with the primary heating tubes.

e) The flow and return headers shall be arranged to ensure an equal flow of water through each tube. For pressures up to and including 350 kPa, connections of 50 mm bore and below shall be made to heater coils using ground-in spherical seated unions. The connections to heating coils of 65 mm bore or greater, and for all sizes where the pressure exceeds 350 kPa, shall be flanged. Provision shall be made for thermal expansion of the tubes, for effective venting of the
Isolating valves shall be provided on inlet and outlet connections, arranged to facilitate easy removal of the heating coil. On any system where the air static pressure at the heater exceeds 500 Pa cover boxes shall be provided over the headers and bends, to minimize air leakage.

(f) The resistance to airflow of the heating coil shall not exceed 65 Pa and the face velocity shall not exceed 4 m/s.

(g) Before leaving the manufacturer’s works the heating coil shall be tested with air under water to 1½ times the working pressure or to 700 kPa, whichever must be the greater and a test certificate issued.

C3.2.12 Electric Type Air Heater Coils

(a) Electric air heaters shall consist of a number of sheathed heating elements of the enclosed type mounted in a sheet steel casing. The elements shall be so installed that they can be removed for cleaning or renewal without dismantling ductwork. The surface temperature of the elements shall not exceed 400°C when measured in an air flow of 2.5 m/s at ambient temperature. A high temperature limit cut-out device with hand reset button shall be incorporated such that the limit device sensor is nearest to and above the heating elements which are energized by the first control step. The device shall operate within two minutes at a temperature of 68.5°C.

(b) The control of electric air heaters, except for remote boosters, shall be interlocked with the fan motor starters and an air flow control of the pressure or sail switch type so that the heaters cannot operate unless the fan is running.

(c) Electric air heaters which are installed as boosters in branch ducts remote from the fans shall have an air flow control of the pressure or sail switch type which shall isolate the heating elements from the electricity supply in the event of the failure of air flow.

(d) The number of elements in the heater shall be the same as or a multiple of the number of steps in the controller. All heaters and heater sections of more than 3 kW loading shall be balanced over 3 phases and the complete heater bank shall be arranged for balanced operation on a 3-phase 4-wire system.

(e) The connections from each element shall be taken to a readily accessible terminal box arranged for conduit entry. Each heater section shall be separately fused and the neutral point of all 3-phase star-connected sections shall be brought out to a link in the terminal box. Near hot areas the wiring
insulation shall be of a quality suitable for the maximum working temperature.

(f) The total resistance of the heater to airflow shall not exceed 15 Pa and the face velocity shall not exceed 6 m/s.

Note for energy efficiency design: Heating by hot water from waste heat reclaim or from heat pump system aiming for high operating efficiency should be considered. The detail of the heating battery is as shown in Sub-section C3.2.11 above and the requirement shall be as described in the Particular Specification to suit the system design.

C3.2.13 Humidification Equipment

Steam humidifiers shall be used. They shall be of the steam injection type using electric elements/electrodes or be of the evaporative pan type with a minimum efficiency of 95%. Steam available from a central plant may also be used.

It shall be possible to isolate the electrical supply from the elements/electrodes and they shall be arranged to facilitate removal for maintenance and replacement. Electric heating elements shall incorporate a high temperature cut-out and shall be interlocked to break the electrical circuit on low water level. Steam injection distribution pipes shall be provided for condensate return and be so designed and installed that free moisture is not carried over into the air stream. Steam generating equipment, other than remote central plant, shall be an integral part of a purpose-made humidifying unit and shall incorporate automatic water-level control, overflow protection and drain connections. Automatic intermittent or continuous blowdown shall be incorporated as appropriate.

The evaporative pan type humidifier shall be positioned so that it is not affected by the radiant heat from heater batteries.

C3.2.14 Additional Modular Sections

Additional modular sections shall be provided with ease for the accommodation of ultra-violet steriliser, heat wheel or other devices as specified for the improvement of air quality and energy efficiency.

C3.3 AXIAL FLOW FANS

C3.3.1 Axial flow fans shall be of either the single-stage type or the multi-stage contra-rotating type with each impeller mounted on an independent motor.

C3.3.2 Casing shall be rigidly constructed of mild steel stiffened and braced to obviate drumming and vibration. Cast iron or fabricated steel feet shall be provided where necessary for bolting to the base or supports. Inlet and outlet ducts shall terminate in flanged rings for easy removal.
C3.3.3 The length of the duct casing shall be greater than the length of the fan(s) and motor(s) in order that the complete section may be removed without disturbing adjacent ductwork.

C3.3.4 Electrical connections to the motor(s) shall be through an external terminal box secured to the casing.

C3.3.5 Impellers shall be of galvanized steel or aluminium alloy; the blades shall be secured to the hub or the blades and the hub shall be formed in one piece. The hub shall be keyed to a substantial mild steel shaft carried in two bearings and the whole statically balanced. Unless otherwise indicated blades shall be of aerofoil section.

C3.3.6 Where axial flow fans are driven by a motor external to the fan casing the requirements of the relevant content in Sections B7 & C7 for pulleys and for V-belt drives and guards shall be met. Unless otherwise indicated a guard is not required for any part of a drive which is inside the fan casing. An access door of adequate size to facilitate inspection, cleaning and other maintenance shall be provided.

C3.3.7 Where axial flow fans of the bifurcated type are indicated the motors shall be out of the air-stream and shall normally be placed between the two halves of the bifurcated casing in the external air. Where hot gases or vapours are being handled the motor and the bearings shall be suitable for operation at the temperature they may experience. The bifurcated section containing the motor shall be mounted vertically in order to maximise convection air flow over the motor.

C3.4 CEILING FANS

C3.4.1 Dimensions

The sweep diameter of the units shall be 1200 mm or as otherwise indicated.

C3.4.2 Capacity

The 1200 mm unit shall be capable of an air delivery of 3.9 m³/s or as otherwise stated.

C3.4.3 Duty

(a) The unit shall be suitable in all respects for operation under ambient air conditions of 40°C and 95% RH.

(b) The unit shall be suitable for operation in 220 V, 50 Hz single phase AC mains.

(c) The unit shall be designed for heavy duty commercial and domestic usage.
(d) The fan shall operate without generating unnecessary noise at all speeds.

C3.4.4 Motor

(a) The motor shall be a totally enclosed, capacitor run induction motor, with internal stator and external squirrel cage rotor.

(b) The rotor shall be mounted in grease lubricated ball bearings.

(c) The power factor shall not be less than 0.85 at any speed.

(d) The motor shall be rated for continuous operation under ambient air conditions of 40°C and 95% RH and the temperature of the windings shall not exceed 50°C after two (2) hours of continuous operation.

(e) All electrical components, cables etc. shall conform to the appropriate specifications or shall be of fully equivalent quality and capacity.

C3.4.5 Blades

(a) The fan shall be fitted with three (3) blades. "Twisted" blades are preferred.

(b) The blade assemblies shall consist of blades manufactured from heavy gauge aluminium securely riveted to steel blade carriers.

(c) The blade carriers shall be manufactured from mild steel plate of not less than 3 mm in thickness and of not less than 40 mm width at the narrowest point, pressed to shape.

(d) Where the blade carriers are twisted to give the required angle of incidence to the blades, there shall be large radius bends to prevent stress concentrations in the blade carriers.

(e) Anti-vibration bushes shall be installed between the blades and blade carriers.

(f) The blade carriers shall be securely fastened to the frame of the motor by machine screws and spring washers, the whole assembly shall be designed and constructed to ensure that there is no possibility of a blade becoming detached during operation.

C3.4.5 Terminals and Capacitor

(a) The plastic terminal block and capacitor shall be mounted in a ferrous metal connecting piece, located between the fan and the down-rod. The leads from the stator windings shall be connected to the terminal block. An earthing terminal,
consisting of a round head brass, screw and washer, shall be provided on the connecting piece. All exposed metal parts of the fan unit shall be connected to this earthing terminal.

(b) The bottom portion of the connecting piece shall be screwed on to the shaft of the motor. The connecting piece shall be tightened onto a shoulder formed on the motor shaft. A 4 mm minimum thickness steel hexagonal lock-nut with lock bracket underneath shall then be fitted and tightened in position. The connecting piece shall additionally be screwed in the fully tightened position by two hardened steel grub screws. These screws shall engage in shallow depressions drilled in the shaft after the connecting piece has been tightened in place to ensure positive locking.

C3.4.7 Down-Rod Assembly

(a) The down-rod assembly shall consist of a down rod and a steel shaft with a hard rubber roller for suspension of the fan. The down rod shall be supplied to the length indicated for the job which shall be measured from the top of the connecting piece to the centre of the pin in the shackle at the top.

(b) The down-rod shall be manufactured from 12 mm bore standard mild steel pipe of not less than 3 mm wall thickness, having an external diameter of approximately 20 mm. It shall be accurately threaded at one end and shall be screwed into the top portion of the fan connecting piece (capacitor housing) from which it shall protrude by a minimum of 2 mm.

(c) It shall be locked in position by two hexagonal steel lock nuts, having a minimum thickness of 6 mm, tightened onto the upper machined surface of the fan connecting piece.

(d) The down-rod shall also be locked to the fan connecting piece by means of a steel split-pin, of not less than 5 mm diameter, passing through both the fan connecting piece and the down-rod.

(e) The split-pin holes in the fan connecting piece shall be of such a diameter that the split-pin is a light push fit there-in. The matching split-pin holes in the down-rod shall be just sufficiently large so that the split-pin shall be a light push fit, when the hole is in its worst position relative to the threading. All burrs and sharp edges shall be removed from the split-pin holes both in the fan connecting piece and the down-rod.

(f) The steel suspension shackle shall be welded to the down-rod. Welding shall be of good quality and to the satisfaction of the Architect. The rubber roller shall be mounted on an 8 mm diameter steel clevis pin secured by a split-pin.
(g) The ends of the down-rod shall be rounded off and free from burrs. There shall be no sharp edges which could cause damage to the insulation of the wiring.

C3.4.8 Suspension Joints and Threaded Parts

(a) Joints along the suspension rod must be of double-locking design, i.e. at least two independent positive locking devices must be employed to prevent a joint from loosening itself.

(b) The maximum clearance between threaded mating parts must not exceed 1% of their mean diameter.

(c) The direction of rotation of the fan shall be such that all screw joints tend to be tightened when the fan is in operation.

C3.4.9 Canopies

Two canopies manufactured from plastic or pressed steel sheet shall be provided and fitted over the upper and lower ends of the down-rod. They shall be fixed to the down-rod grub screws.

C3.4.10 Balance

(a) All fans shall be fully balanced after assembly, with any necessary adjustment being made to ensure that they shall not oscillate due to out-of-balance forces.

(b) All blades shall be given a single identification number, or letter, permanently stamped on the supply side, with a corresponding mark stamped on the motor body so that the fan blades may be reassembled in the correct position.

C3.4.11 Finish

The whole fan shall be finished in high quality stove-enamel, white, ivory or other colour where required by the Architect.

C3.4.12 Speed Regulator

(a) The speed regulator shall be of the choke type with five (5) speed and an "OFF" position, built on a moulded plastic, or insulated steel base and enclosed by a moulded plastic cover. The cover shall be white or ivory or other colour to match the fan.

(b) An earth terminal shall be provided on the base with an earth wire permanently connected to the steel core of the choke unit.

(c) The speed regulator shall move smoothly and easily between positions.
C3.4.13 Inspection

At least one typical unit for those to be supplied for a given Contract shall be submitted for an acceptance test carried out for the Architect before delivery of any quantity is made to the Contract Site.

The test units shall be provided and collected by the Contractor at no extra cost to Architect.

C3.5 CENTRIFUGAL FANS

C3.5.1 Centrifugal fans for high-velocity high-pressure systems as defined within HVCA Standard DW/144, shall be of the backward bladed type.

C3.5.2 Centrifugal fans with motor brake power of 7.5 kW or more shall be of the backward bladed type having a fan total efficiency not less than 75%.

C3.5.3 Fan casings shall be constructed to permit withdrawal of the fan impeller after fan installation. Fans other than those in factory constructed air handling units (AHUs) shall be provided with flanged outlet connections and spigoted inlet connections suitable for flexible joint connections except those for use with negative pressures greater than 500 Pa in which case inlet connections shall be flanged.

C3.5.4 All fan casings of 900 mm diameter or greater shall be provided with removable access panels which shall incorporate purpose-made air seals. The sizes of access panels shall be such as to facilitate cleaning and maintenance of the impeller and shall not be less than 600 mm X 600 mm.

C3.5.5 For all kitchen extract ventilation fans an access door, for inspection and cleaning, shall be fitted to the scroll casing in an accessible position; it shall be of full width of the impeller. A plugged drain point shall be fitted at the lowest point of the fan.

C3.5.6 Permanent indication shall be provided to show the correct direction of rotation of the fan impeller.

C3.5.7 Impellers shall be of galvanized steel or aluminium alloy where indicated, of riveted or welded construction, with spiders or hubs of robust design, and shall be capable of running continuously at ten percent in excess of normal speed. Impellers shall be keyed to a substantial mild steel shaft and the impeller complete with shaft shall be statically and dynamically balanced and tested for satisfactory overspeed performance before leaving the maker's works.

C3.5.8 Fan shaft shall enable pulley to be mounted at both ends. Shaft bearings of belt driven single inlet fans shall be truly aligned and rigidly mounted on a pedestal common to both bearings. Double inlet, double width fans shall have a pedestal mounted bearing at each side of the fan. Fan bearings shall be of the ring oiling sleeve type, or the ball or roller type.
Where silence is important the bearing pedestal shall not be attached to the fan casing, instead ring oiling sleeve type bearings shall be supplied.

C3.5.9 Centrifugal fans shall be driven by electric motors through V-belt drives complying with the relevant content in Sections B7 & C7.

C3.5.10 Single phase powered variable flow centrifugal fans where specified shall be fitted with variable inlet vanes which shall be matched to the fan performance to give stable control. Vanes shall be closely interlocked to ensure movement in unison. Operation shall be manual or automatic as indicated. Where manual control is indicated, the operating device shall facilitate positive locking in at least five different positions. Vane blades shall not vibrate or flutter throughout their operational range.

C3.5.11 Three phase powered variable flow centrifugal fans where specified shall be variable speed driven. Variable speed drive shall be in accordance with Sections B7 & C7 of this General Specification.

C3.6 FAN COIL UNITS

C3.6.1 General

Fan coil units shall comply with quality standard ISO9001/9002 and be 'type' tested. The Contractor shall submit the make and type of each fan together with the 'type' test certificate for the Architect's approval. The origin of the fan shall be from the country where the 'type' test was conducted.

Fans, filters, cooling coils, heating coils, motors, thermal and acoustic insulation shall comply with the appropriate sections of this General Specification and the following requirements:-

(a) Fans shall be of the Double Inlet Double Width (DIDW) forward curved centrifugal or tangential flow types and shall be of mild steel, aluminium, reinforced glass fibres or rigid plastic material as specified in Particular Specification.

(b) Air filters shall be as indicated in the relevant content of Section C1 but with an efficiency of not less than 50% when tested in accordance with BS EN779.

(c) Motors shall be quiet running and have sleeve or ball bearings factory lubricated for life. Motor windings and electrical components shall be impregnated or protected to avoid trouble from condensation. The fan motor shall be of the single phase permanent split capacitor type provided with three speed tapped windings.

(d) All fan coil units capacity and air flow rate shall be selected based on the performance of the units at medium fan speed.
In selecting the fan coil units, allowance shall be made for the actual resistance imposed on the air flow of the units due to ducts and grilles. The added resistance is to be applied to all fan coil units whether shown to have ducts connected or not, and shall be taken as not less than 50 Pa external to the unit.

The thermal, volumetric and acoustic performance of fan coil units shall meet the requirements indicated and testing and rating shall be in accordance with BS 4856.

3.6.2 Casings

Casings shall be of G.I. sheet metal with thickness not less than 1.0 mm suitably stiffened to minimize drumming and vibration and shall be protected against corrosion and finished inside and outside with stoved primer. All corners shall be rounded off without sharp edges. Casings shall be lined with material to act as both thermal and acoustic insulation which shall comply with the relevant of Sections B11, C11, B8 & C8. Casings shall include space for pipework connections and valves, and there shall be ready access to the fan and motor, filter, damper, drain pan, pipework connections and valves, for maintenance purposes.

The motor and fan shall be mounted on a detachable mounting chassis that can be removed from the fan coil enclosure as one assembly (with extended cables) to facilitate fan and motor cleaning. It shall then also be possible to remove the fan impeller scroll casing in order to properly clean the fan blades. Fan and motor assemblies shall be complete with neoprene rubber anti-vibration mountings.

C3.6.3 Coil

(a) Cooling coils shall be minimum two-row and shall include an air vent cock and drain valve.

(b) The chilled water cooling coil shall be ARI certified and constructed from seamless copper tubes mechanically bonded to aluminium fins.

(c) Each coil shall be provided with motorized 2-way solenoid control valve and isolation valves. Flexible pipe connectors complete with union joints to facilitate removal of the entire unit shall be provided. The connector shall be stainless steel braided polymer tubing limited to 300 mm long and suitable for the system pressure.

(d) Working pressure of coils shall suit specific requirements.

C3.6.4 Components

(a) All units shall include an easily removable filter capable of treating the total air volume. Filters shall, unless otherwise
specified, be washable. It shall be supported in a stiff aluminium/stainless steel withdrawable frame.

(b) Drain pans shall be made of one piece stamped stainless sheet steel with no weld and protected against corrosion, or made of plastics or reinforced glass fibre materials insulated with a minimum of 13 mm thick flexible closed cell elastomeric insulation. Drain pans shall be large and deep enough to collect all condensate from the coil, return bends and pipework connections. The pan shall be removable and have a slight fall to the drain connection. For units whose loads include a high proportion of latent cooling the fall to the drain point and the size of the drain connection shall be adequate to deal with the condensed moisture.

C3.6.5 Arrangement of Units

The arrangement of units (e.g. wall, floor or ceiling mounted), the position of inlet and outlet grilles if any, the need for G.I. sheet metal casing etc. shall be as indicated.

C3.6.6 Controls, Dampers and Grilles

Fan coil units shall have a combined room temperature sensor complete with 3-speed controller and heating/cooling mode selector as specified. Where indicated they shall have connections for both fresh and recirculated air and shall include a damper which shall be adjustable to give up to 25% of the fan capacity drawing from the fresh air source. Outlet grilles shall be capable of adjusting the direction of airflow without adversely affecting pressure drop. On floor mounted units, supply grilles shall be on the top of the unit.

C3.6.7 Noise level

The noise data provided shall include an octave band analysis of the sound power level of each unit when operating at its full or the stated design speed.

C3.6.8 Electric Heaters for Fan Coils

Electric heaters shall be of maximum 2 kW capacity of the black heat sheathed element type, plain or finned, and shall be provided with a safety cut-out thermostat set to operate at 50°C.

Sail switch is to be fitted for each heater battery and is to be connected in series with the safety cut-out thermostat to switch off the heater in the event of reduced air flow.

The mounting, arrangement and terminals etc. for Electric Duct Heaters shall be in accordance with Contract Drawings or other installation standard approved by the Architect.
C3.7 CASSETTE TYPE FAN COIL UNITS

C3.7.1 Generally, the cassette fan coil units shall comply with Sub-section C3.6 of this General Specification.

C3.7.2 The fan coil unit shall be of integrated cassette type which combines the supply air slot, return air grille, fan, casing, cooling coil, heating coil or electric heater (if required) into a single unit. No connection of ductwork is allowed except for fresh air.

C3.7.3 Fan coil units shall be selected at design duty and specified noise level with fan running at medium speed.

C3.7.4 Each fan coil unit shall be provided with a combined room temperature sensor complete with 3-speed controller and heating/cooling mode selector as specified. Remote control unit shall be provided as specified.

C3.7.5 Air cooling coil shall be constructed with copper tubes and shall be arranged horizontally. Tubes shall have brazed copper return bends. Fins shall have smooth drawn collars of length equal to fin spacing and mechanically bonded to tubes. Fins shall be of the plate type, corrugated to ensure maximum air contact. All coils shall have an air release valve and a drain valve. Working pressure of coil shall be of a minimum of 1200kPa and to suit system pressure design. Connection of water piping shall refer to Sub-section C3.6.3(c).

C3.7.6 Each fan coil unit shall be provided with a stainless steel drain pan situated beneath the cooling coil and arranged so that all moisture will collect in and drain from the pan. Drain pans shall be insulated externally with a minimum of 25 mm approved type foamed plastic. Each drain pan shall be fitted with a drain pipe which shall be connected via suitable runs (correctly laid to fall) to the drainage system. Drain pans shall have copper male connectors for connection to the condensate drain. The connector shall be positioned to ensure rapid discharge of moisture from the pan.

C3.7.7 Built-in condensate pump shall be provided for the removal of condensate. A water sensing system with low, high and warning limits shall be provided which actuates the running of condensate pump at high water limit and trigger the alarm system at warning level. When water level reaches the warning limit, the sensing system shall cut off the unit operation. An alarm signal shall be given locally. The signal shall be connected to CCMS or remote indication system as specified. Condensate pump shall be designed to run continuously at some essential areas as specified. The power source for condensate pump and the associated control system shall be independent from that of the fan coil unit such that the pump can still be operated after the units has been switched off.

C3.7.8 The filter media shall be of the washable type and shall be enclosed in a one-piece formed stainless steel frame with covers flush mitred and reinforced by a die-formed inverse bead.
C3.7.9 Fan shall be of the quiet running direct driven centrifugal type with aluminium blades mounted to a solid steel shaft. Fan motors shall be of the ‘split capacitor’ type suitable for single phase electrical supply. The motor shall be resiliently mounted to the fan tray or scrolls. The motor/fan tray assembly itself shall also be resiliently mounted to the casing structure.

C3.7.10 Manually adjustable louvres for directional airflow shall be provided for supply air slot in each fan coil unit. Options shall be given to choose from 2-way, 3-way or 4-way supply air discharge.

C3.8 IN-LINE CENTRIFUGAL AND MIXED FLOW FANS

Mixed flow fan casings shall be rigidly constructed of mild steel, or aluminium alloy stiffened and braced where necessary to obviate drumming and vibration. Mounting feet shall be provided where necessary for bolting to a base or supports. Inlet and outlet shall terminate in flanges to facilitate removal. Stator vanes shall be of mild steel or aluminium alloy. The unit shall be designed to facilitate access to the impeller. Where motors are mounted external to casings, drives and guards shall be provided in accordance with Sections B7 & C7. An access panel with purpose-made air seal shall be provided in the fan casing; the access panel shall be sized and so positioned as to facilitate maintenance.

C3.9 MECHANICAL ROOF EXTRACT UNIT

The fans used in roof extract units shall meet with the appropriate requirements of the preceding content relating to fans generally and in particular to the types of fans involved. The materials of cowls and bases shall be resistant to weather, solar radiation and appropriate to the location of the unit and type of fan installed. Casings shall be formed to facilitate a weatherproof fixture to the building structure. Adequate access to electrical supply terminals and lubrication points shall be provided by means of hinged cowls or otherwise as appropriate. Back-draught dampers and/or fire release dampers shall be provided where indicated. Bird entry preventive guards of not greater than 25 mm mesh shall be provided as an integral part of the unit.

C3.10 PROPELLER FANS

Impellers shall be of steel or aluminium; the blades shall be fastened to the hub or the blades and hub shall be formed in one piece. The bearings may be ball, roller, or sleeve type. Propeller fans may be ring mounted, diaphragm mounted or diaphragm mounted in a casing, as indicated.

The tip speed of propeller fans shall, unless otherwise indicated, not exceed 20 m/s. All ring mounted propeller fans which are exposed, i.e. not installed within a ductwork or other enclosure, shall be adequately protected by safety guards.
C3.11 PROTECTIVELY COATED FANS AND FANS FOR CORROSIVE OR HAZARDOUS APPLICATIONS

Where fans are required to handle toxic, corrosive, flammable, explosive or high temperature gases. The materials and form of construction shall be selected and suit the particular application. Bearings and lubrication arrangements shall be suitable for the conditions. Protectively coated fans shall meet with the appropriate requirements of the previous content relating to fans generally and to particular types of fans; the form of protection shall be as indicated. Where a protective coatings is required for use with corrosive gases the coating shall cover all parts of the complete fan, motor and casing assembly which will be in contact with the corrosive gases. No fan shall be installed if the protective coating has been damaged in any way. Impellers shall be of coated steel, stainless steel, aluminium or fire-proof plastic as indicated.

Where fans are installed in a potentially explosive atmosphere the special requirements will be indicated in the Particular Specification and are to be rigidly adhered to.

C3.12 ROTARY FANS (WALL OR CEILING MOUNTED)

C3.12.1 Capacity

The unit shall be capable of an air delivery of not less than 1.1 m$^3$/s.

C3.12.2 Dimension

The blade sweep diameter of the unit shall be 400 mm.

C3.12.3 Duty

(a) The unit shall be suitable in all respects for operation in ambient air conditions of 35°C and 95% RH.

(b) The unit shall be suitable for operation on 220 V, 50 Hz, single phase AC supply.

(c) The fan shall not require periodic lubrication.

C3.12.4 Construction

(a) These units shall be of deluxe and pleasing appearance with smooth safe edges and of "easy-to-disassemble" design for cleaning. Units not considered of suitable appearance may be rejected by the Architect.

(b) The fan shall have high quality aluminium or plastic blades.

(c) The fan shall be fully balanced after assembly.
(d) The blades shall be enclosed by a high quality chromium plated metal wire-mesh metal guard. The gap in between the guard wires shall not be greater than 15 mm at any point.

(e) The fan shall be provided with rotary mechanism for a rotational sweep of 360° when mounted on the ceiling for rotary ceiling fan or for a swing of 150° when mounted on a wall or column for rotary wall fan.

(f) The whole unit shall be finished to manufacturer's standard light colour or as otherwise approved by the Architect.

C3.12.5 Electrical

(a) All electrical components, cables etc. shall conform to the appropriate standards and specifications stipulated in Sections B7 & C7.

(b) All exposed metal parts of the unit shall be suitably earthed via the 3 core flexible cable.

(c) The fan shall be provided with speed regulator and be capable of being switched on and off by a remote 5A switch.

(d) The fan shall be provided with an adequate length of 0.75 mm² 3 core PVC insulated and sheathed flexible cable and connected to the associated socket outlet. Where provided but not fixed, the cable provided shall be two meters in length.

C3.12.6 Inspection

As Sub-section C3.4.13.

C3.13 TERMINAL AIR CONTROL DEVICES

C3.13.1 General

(a) Terminal units shall be factory fabricated and tested in accordance with British Standard BS 4979, BS 4954, BS 4857 (or related content of ISO5220, ISO5221 and ISO5219) where appropriate.

(b) Casing of the unit shall be manufactured from galvanised steel sheet of minimum 0.7 mm thick having round edges to form a rigid construction.

(c) Noise including in-duct sound power level, which emitted through the unit casing shall not exceed the value as indicated and/or as stated in Section B8 & C8 of this General Specification.
(d) The entire unit shall be internally lined with thermal and acoustic insulation in compliance with the relevant content in Sections B11 & C11 and B8 & C8 enclosed in a galvanised perforated metal liner. The lining shall be securely fixed and shall be proof against erosion by the air flow. The acoustic and thermal insulation shall comply with NFPA-90A, UL-181 and BS 476 Part 4, 5, 6 & 7 standards (or the related content of ISOR1182, ISO5667, ISOTR5658-1, ISO10295-2 & 10295-3) and the requirements of the Fire Services Department.

C3.13.2 Induction Units

(a) Filters, cooling coils, heating coils and thermal and acoustic insulation shall comply with the appropriate sections of this General Specification, with the following exceptions or alternatives:-

Air filters shall be as specified in Sub-section C3.6.1(b) for fan coil units.

Unless otherwise indicated, cooling coils and/or heating coils shall be formed of copper primary surface tubes with aluminium secondary surfaces.

(b) Casings shall include space for pipework connections and ductwork as necessary, and there shall be ready access to the filter, the primary air nozzles and any valves and controls.

(c) Primary air plenums shall be treated with thermal and acoustic insulation which shall comply with the relevant content of Sections B11 & C11 and B8 & C8. Units shall be complete with a suitable device to regulate primary air pressure and air volume flow rate. Primary air nozzles shall be arranged to induce an even secondary circulation across the cooling and/or heating coils. The unit air outlet shall incorporate means of directional control of air supply where indicated.

(d) Cooling/heating coils shall include an air cock and shall be effectively sealed to prevent air by-pass around the coil. Drain pans shall be of a material which is resistant to corrosion or is protected against corrosion and shall have a slight fall to a drain connection.

(e) The arrangement of units (e.g. wall or ceiling mounted), and the need for sheet metal casing shall be as indicated.

C3.13.3 Single Duct Constant Air Volume (CAV) Terminal Units

(a) Unit shall be constructed in accordance with Sub-section C3.13.2 where appropriate.
(b) Units shall incorporate a self-acting constant flow rate device. The pressure drop across the unit at design air volume flow rate shall not exceed 250 Pa.

C3.13.4 Single Duct Variable Air Volume (VAV) Terminal Units

(a) Unit shall be rated in accordance with ASHARE Standard 36-72 and Air Diffusion Council Test Standard 1062R4. The performance data shall be certified by a recognized laboratory approved by the Architect.

(b) Unit shall be of the pressure independent type throughout the entire range and shall be capable of resetting the air flow to $\pm 5\%$ of the nominal air flow regardless of the change in the system pressure.

(c) The unit shall be capable of being reset to any airflow between zero and the maximum catalogued air volume automatically to compensate for duct pressure fluctuation.

(d) The air velocity sensor shall measure the true velocity across the inlet of the unit and be unaffected by changes in duct air temperature and humidity. The sensor shall be field replaceable without opening the associated ductwork.

(e) The entire package shall be calibrated and factory-set for the maximum and minimum flow rates as specified but shall be capable of easy re-adjustment in the field. Each terminal box shall be provided with factory-calibrated, direct reading air flow indicator. Separate gauge taps shall be provided for field re-calibration and commissioning.

(f) The velocity controller and the damper actuator shall be of an integral unit directly mounted onto the damper shaft. The actuator shall be capable of operating in the stalled position without overheating or mechanical damage. Mechanical limit switch will not be accepted. The damper shall remain in a fixed position when electrical power source is interrupted. The control equipment must be easily accessible through an access door provided with quick-release fasteners.

(g) The damper shall be made of heavy gauge galvanized steel with peripheral gasket, pivoted in self-lubricating bearing. In the fully closed position air leakage past the closed damper shall not exceed 2% of the nominal catalogue rating at 250 Pa inlet static pressure.

(h) VAV terminal unit shall be pneumatic, electronic or DDC controlled as specified. One thermostat shall be provided for each VAV terminal unit unless otherwise specified. The thermostat offered shall match the unit and include temperature set point and velocity adjustment point located inside.
The thermostat shall have a calibrated scale showing set point temperature with a constant approximately 1°C proportional band regardless of minimum and maximum velocity settings. Air flow set point shall be adjusted by screw and voltmeter tap in the thermostat or by other approved means for both high and low air volume limits. The location of the thermostat shall be determined on site.

(i) The unit shall not be selected at the top of the catalogue range in order to ensure it meets with the specified room noise level requirement.

(j) Circular connection spigot of insertion dimensions, with self sealing rubber gasket shall be provided at both the inlet and outlet of the unit. Each multi-outlet section shall be complete with at least one spare outlet, capped for future use.

(k) Unit shall be complete with a mixing attenuator section where specified.

The attenuator shall be factory-fitted to the basic unit and of a length not less than 400 mm. The casing shall be constructed as the terminal unit, but with acoustic insulation of mineral wool with a minimum density of 70 kg/m³.

(l) Unit shall be complete with electric heater section where specified. Heater casing shall be made of minimum 0.7 mm thick galvanized steel sheet insulated by 30 mm thick mineral wool lined with staple fibre fabric. The heater shall be easily withdrawn from the casing for servicing and maintenance. Heating element shall be of the shealth and black heat type. The heater shall be controlled by contactor and step controller fully interlocked with a sail switch and duct type overheat thermostat with fail safe feature and manual reset.

C3.13.5 Dual Duct Terminal Units

Dual duct terminal units shall be constructed as single duct CAV unit and VAV unit and shall incorporate devices for varying the proportions of hot and cold air and for providing thorough mixing of the air.

C3.14 GRILLES AND DIFFUSERS

C3.14.1 General

(a) The grilles and diffusers shall be rated in accordance with ASHRAE standard 36-72 and Air Diffusion Council test standard 1062R4.
(b) All grilles and diffusers shall have concealed fixing system and shall have quick release frame to facilitate cleaning.

(c) All supply grilles and diffusers shall be mounted on substantial frame and shall be provided with soft rubber or felt joining ring inserted under the frame to prevent air leakage and the formation of condensate on the fitting.

(d) All grilles and diffusers shall not be less than the size indicated; where no size is given they shall be capable of handling the air flows and distribution indicated without producing unacceptable air flow noise. The Contractor shall select the supply air grilles and diffusers to achieve good air distribution and adequate air movement in the conditioned space.

(e) In order for the ceiling grilles and diffusers to match with the false ceiling layout pattern, the actual size of the grilles and diffusers shall be confirmed by the Architect before ordering.

For all grilles and diffusers which are smaller than the ceiling tile on which they are installed, they shall be located in the centre of the ceiling tile. The exact location of the ceiling grilles and diffusers shall be co-ordinated with other services. The Contractor shall confirm the exact location with the Architect before works commence.

Where grilles and diffusers are to be incorporated into false ceilings before any grilles or diffusers are installed into ductwork or fan coils, the Contractor shall ensure that the Building Contractor marks out the ceiling line on the adjacent plastered walls or columns and also indicates where ceiling tee bars line up or the ceiling joints occur in order that such datum can be worked to.

(f) The finishing colour of the grilles and diffusers shall be approved by the Architect as different colours may be specified in different areas. The Contractor shall co-ordinate with the Building Contractor and other specialist Contractors especially the ceiling and electrical Contractor for the integration of the air diffuser into the ceiling and luminaire (for light troffer diffuser).

C3.14.2 Grilles

(a) Grilles shall be of steel, aluminium, PVC or as otherwise indicated. Steel grilles shall be protected against rusting and supplied in fully finished stove-enamelled or otherwise specified condition.

(b) Each supply air grille shall have two sets of separately adjustable louvres, one set horizontal and one set vertical, and shall be complete with an opposed blade multi-leaf
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Section C3.14.3 Diffusers

(a) Diffusers shall be of steel or aluminium. Steel diffusers shall be protected against rusting and shall be stove enamelled for finished colour approved by the Architect. Diffusers shall incorporate an edge seal; diffusers mounted on ceilings shall have anti-smudge rings. Pan type diffusers shall be provided except where cone type diffusers are indicated.

Diffusers shall be provided with volume control dampers of the iris, flap or sleeve type which shall be adjustable from the front of the diffuser. Where the length of a vertical duct to a diffuser is less than twice the diameter of the diffuser an equalizing deflector shall be fitted.

The design of the supply air diffuser shall be capable to induce adequate air movement and provide the throw to cover the entire air-conditioning space without causing air turbulence and cold draft.

(b) Linear diffusers shall be constructed of extruded aluminium section and include a control damper at the rear of the vanes giving volume control down to complete shutoff and operated from the face of the diffuser. Linear diffusers for supply air shall have adjustable blades to give directional control of air flow. The linear diffuser shall be capable of maintaining a horizontal discharge pattern at a turn down
ratio down to 20% of the maximum specified air volume without air dumping.

The linear diffuser shall be complete with factory fabricated plenum with suitable inlet connection for flexible ductwork. The plenum and diffuser neck shall be constructed of galvanised steel sheets internally lined with 25 mm 48 kg/m³ glass cloth faced fibreglass insulation enclosed in galvanised perforated metal liner.

The insulation shall comply with NFPA-90A, UL-181 and BS 476 Part 4, 5, 6 & 7 standards (or related content of ISOR1182, ISO5667, ISOTR5658-1, ISO10295-2 and ISO10295-3).

Where linear diffusers are mounted in a continuous line there shall be means of ensuring alignment between consecutive diffusers and of equalizing pressure behind the vanes. The dummy portion of the diffuser shall be internally covered by a demountable galvanized metal enclosure to block the view into the ceiling void from below.

(c) The square face diffuser for VAV system shall be constructed of aluminium and with large turn down ratio.

Each ceiling mounted square face diffuser shall have a factory assembled diffuser and an air plenum. The air plenum shall be provided with dividing plates such that the diffuser back is divided into an annulus area and a square central area. In the entry to the diffuser plenum, the flow cross section shall also be divided into two parts, one part serving as a bypass and the other equipped with a self contained, weight balance damper. The damper shall be balanced with a weight in such a way that the horizontal outlet jet velocity remains nearly constant over a flow rate range of 100 to 20% of maximum in order to prevent stagnant area, wide temperature gradient and drop of air jet in the conditioned area.

(d) The linear slot diffuser shall be constructed of extruded anodized aluminium, with multiple slot for the required air flow rate.

Each diffuser shall be complete with a factory fabricated plenum of the same construction as the linear diffuser.

C3.15 ENERGY EFFICIENCY AND PERFORMANCE

(a) The efficiency of fan and motor used for all air treatment equipment shall be as specified in Sub-section C3.5.2 – Fan System under the Code of Practice for Energy Efficiency of Air Conditioning Installation issued by
the Electrical & Mechanical Services Department and Section C7 of this General Specification.

(b) The type of insulation used shall have optimised thermal conductivity, and the design of the insulation thickness for pipe, drain pan, ductwork, panel enclosure etc. of the air handling equipment shall be in accordance with Section C8 - Insulation under the Code of Practice for Energy Efficiency of Air Conditioning Installation issued by the Electrical & Mechanical Services Department plus 10% or better, increase in thickness as safety margin.

(c) The Contractor shall submit relevant factory test certificates and field test records for calculation and assessment by the Architect.

C3.16 DESICCANT DEHUMIDIFIERS

C3.16.1 Wheel Type Desiccant Dehumidifier

(a) The dehumidifier shall be of the absorption or adsorption type and complete with rotor, electric or gas type reactivation heater, process air fan, reactivation fan, process air prefilter, reactivation air prefilter, control panel and all other accessories for a complete unit. The heater shall be fitted in a factory built unit casing.

(b) Rotor shall be impregnated with desiccant such as lithium chloride, silica gel, aluminium oxide or other specified type. The desiccant shall be incombustible, resistant to chemicals and non-dusting. The rotor shall have a service life of minimum 8 years with non-stop operation. The seals between the process and reactivation airflows shall be designed to good standards, and their low frictional properties shall guarantee long and continuous service life.

(c) The casing of the dehumidifier shall be constructed of sheet steel with oven-curved enamel coating to minimize corrosion. Casing shall comply with leakage standard to Eurovent Document 2/2, Class B and the leakage volume shall be of maximum 0.81 l/s per cu. meter at 1000Pa.

(d) A control panel shall be provided for the control of the dehumidifier. The control panel shall include control mode switch for switching between manual and humidistat operation. Indicators for power on, unit running, alarm (for high temperature cut-out, fan motor overload unit, trip and high humidity, etc.), reactivation fan running, reactive heater on, rotor drive motor running, process fan running, humidity normal, and any other control indication requirements as specified. There shall also be digital displays for fan speeds, humidity level, and reactivation temperature readings etc.
(e) The heater control shall be of multi-step. The dehumidifier shall be capable of operating with the services conditions as specified under Section A3 of this General Specification.

(f) The unit shall be capable of local or remote control, and be complete with interlock control for operation with the connecting air handling unit. The unit itself shall be complete with built-in direct digital controller (DDC) for all control and monitoring functions.

(g) The following safety devices shall be provided as a minimum requirement:

- Electric safety interlock to prevent the dehumidifier from running with the electric control panel open or the mechanical access panels removed,

- Automatic shutdown in case the control system detected a fault,

- Two independent thermostats for the heater shall be provided to trigger automatic shutdown in accordance with IEC regulation.

C3.16.2 Liquid Type Desiccant Dehumidifier

(a) The unit shall employ an approved liquid type desiccant as the dehumidification media.

(b) The unit shall comprise three separate operation sections (i.e. collection, heat pumping and regeneration).

(c) In the collection operation, liquid desiccant shall be continually added to the top of a honey comb cellulose material which shall form a flowing liquid film. The untreated air (i.e. process air) shall be cooled and dehumidified when flowing through the liquid desiccant.

(d) The heat pump section shall transfer the heat of the liquid desiccant absorbed during collection operation to the regeneration operation.

(e) The liquid desiccant shall be heated in the regeneration section. The moisture previously collected shall be removed by the regeneration air stream following the same operation principles in collection section.

(f) The equipment shall be a single compact unit of weatherproof design.
The exhaust fan shall be completed with a safety front grille at suction side and shall be suitable for installation on wall or window opening. Cord control is not acceptable.

Electrical operated shutter blades, covered by internal grilles, shall be overlapped and interlocked for maximum back-draught protection.

Each fan shall be fitted with quiet motor. The shutter mechanism shall be of quiet and vibration free operation.
C4.1 ELECTRICAL WIRING

Refer to Section C7 for Electrical wiring & cable material specification.

C4.2 AIR COOLER CONTROL

Unless otherwise specified, the output of chilled water cooler batteries shall be controlled by modulating two or three-way valves having an valve authority as indicated in the Particular Specification or Contract Drawings.

(a) All valves shall be sized in accordance with the recommendations of the manufacturer to assure fully modulating operation.

(b) Valves shall be sized on fully open pressure drop equal to the pressure drop of coil under 120% of design flow.

(c) Control valves shall be normally closed, electrically operated, cage-guided, stainless steel trim, flanged cast-steel body.

(d) Valve opting pointer shall be provided at each valve actuator for direct indication of valve opening.

(e) A manual override device together with auto/manual switch and automatic change-over relay shall be provided as the manual setting facility for the control valve opening and back-up in case of local controller outage.

(f) Valve actuators shall be mounted directly on the control valve without the need for separate linkage and the need for any adjustment of the actuator stroke. Actuators shall have a manual operation capability.

(g) All valve actuators with valve size over 50 mm diameter shall have a spring return for fail-safe operation on power failure.

C4.3 AIR HEATER CONTROL

C4.3.1 2-Way or 3-Way Modulating Valves

Unless otherwise specified, the output of hot water air heater batteries shall be controlled by modulating valves having an authority as indicated in the Particular Specification or Contract Drawings.

All valves shall be sized in accordance with the recommendations of the manufacturer to assure fully modulating operation.
Valves shall be sized on fully open pressure drop equal to the pressure drop of coil under 120% of design flow.

Control valves shall be normally closed, electrically operated, cage-guided, stainless steel trim, flanged cast-steel body.

Valve opting pointer shall be provided at each valve actuator for direct indication of valve opening.

A manual override device together with auto/manual switch and automatic change-over relay shall be provided as the manual setting facility for the control valve opening and back-up in case of local controller outage.

Valve actuators shall be mounted directly on the control valve without the need for separate linkage and the need for any adjustment of the actuator stroke. Actuators shall have a manual operation capability.

All valve actuators with valve size over 50mm diameter shall have a spring return for fail-safe operation on power failure.

C4.3.2 Electric Ductwork Heaters

Specifications for the electric ductwork heaters shall be referred to Subsection C3.2.12. They shall also comply with the requirements of the Fire Services Department.

C4.3.3 Differential Pressure Switches

Differential pressure switches shall be able to de-energize the heaters when the air flow stops.

Differential pressure switches are designed for use only as operating controls. Contractors are responsible to add devices (safety, limit controls) or systems (alarm, supervisory systems) to protect against control failure.

The operating temperature range of the pressure switches shall be from 40°C to 75°C.

The diaphragm housing shall be made of cold rolled steel with zinc plating.

C4.4 ELECTRICAL/ELECTRONIC (LOCALISED) CONTROL SYSTEM

The systems shall be operated at single phase mains voltage or at extra low voltage such as 12 or 24 volts as indicated in the Particular Specification.

Where a particular manufacturer’s system is offered and accepted, the installation shall be installed to comply with that manufacturer’s recommended technical details and methods of installation.

C4.4.1 Standalone Direct Digital Controllers/Outstation (DDC/O)
Unless otherwise specified, the direct digital controllers shall have sufficient memory to support its own operating system and databases, including:

(a) Memory

The RAM memory of the open processor shall be of 2 Mbytes RAM;

Each controller shall have sufficient memory to support its own operating system and database including:

- Control Processes
- Energy Management Applications
- Alarm Management
- Historical / Trend Data for all points
- Maintenance Support Applications
- Operator I/O
- Manual Override Monitoring

The memory board shall be expandable to a larger size as needs grow.

(b) Communication Ports

Each controller shall be equipped with at least two communication ports and one parallel port for simultaneous operation of multiple operator I/O devices such as modems, printers, personal computers, and portable operator’s terminals.

The controller shall have provisions to allow temporary use of portable devices without interrupting the normal operation of the permanently connected modems, printers or network terminals.

(c) Input / Output (I/O)

The point terminal modules shall be available for analogue input or output and digital input or output point types.

These modules shall be quickly and easily snapped into place without tools, and without having to re-terminate wires for fast servicing.

Modules shall be snapped in and out without powering down the field panel to minimise any system downtime.

Manual override shall be available on digital and analogue outputs to allow the user to manually control the position of the end device.

(d) Expandability
Each outstation shall be factory pre-wired comprising a factory fabricated metal enclosure, hinged door with master lock and name plate holder. The outstation shall be of modular design with standard function modules or similar to accept plug in printed circuit cards.

Each outstation shall be loaded up to 85% capacity only; the remaining 15% shall be for future expansion.

Each outstation shall contain interface hardware modules to accept a plug-in portable operator terminal (POT) with visual display and analogue facility to enable commissioning and fault finding to be achieved.

(e) Indicating Lamps

The direct digital controller shall provide local LED status indication for each digital input and output.

Status indication shall be visible without opening the panel door.

(f) Real Time Clock (RTC)

The real time clock shall be able to display in the forms of year, month of the year, day of the month, hour of the day, and minutes.

(g) Automatic Start After Power Failure

The control station shall be provided with a power fail safe and restart feature.

An orderly restart controlled from the data processing controller shall occur on resumption after a power failure without manual intervention.

There shall be no loss of system memory on power failure.

(h) Battery Backup

Battery shall be able to support the real time clock, programme, and all volatile memory for a minimum of 60 days.

When the battery replacement is necessary, the open processor shall illuminate a “battery low” status LED and shall send an alarm message to the selected printer or terminals.

(i) Time Scheduling
The following commands shall be able to be time-scheduled for issue at a later day and time:

- Start and stop a point
- Change alarm limits, warning limits or set-point
- Lock/unlock point reporting or point control
- Demand limit target setting
- Alarm summary

Separate schedules shall be stored for:

- Regular weeks
- Special weeks
- Holidays

After recovery from a power failure, the system shall determine any time-scheduled commands which should have been issued during the period that the power was off. These commands shall automatically be issued.

The system shall allow holidays to be scheduled with a minimum of one year in advance.

(j) Alarm Management

Each analogue point shall have the following defined:

- High Alarm Limit
- High Warning Limit
- Low Warning Limit
- Low Alarm Limit
- Differential

When an analogue point goes outside the High Warning or Low Warning Limit for more than one minute, a user defined warning message shall be sent to the appropriate alarm printers.

When a binary point goes into alarm, a user defined alarm message shall be sent to the appropriate alarm printers.

When a point returns to normal, the event shall be recorded in the printer output.

When the point module is placed in override, an alarm shall be sent to the output of the printers.

C4.4.2 ACMV Sub-System Controllers

Temperature/humidity/pressure controllers shall be of the plug-in proportional type with integrated circuits. Controllers shall be capable of accommodating up to three separate outputs. Each shall have separate zero and proportional band adjustments. Indicating lamps shall be provided for each output that will vary in intensity to indicate the amount
Controllers shall be available with either 0 to 20V or 0/4 to 20mA DC proportional output, two positions, or any combination. Controller shall have internal switches for each output to change the output signal to either direct or reverse. Controller shall be available with integral electronic circuit for absolute high or low limit control.

Air contamination controllers shall be available in one or two stages. Controller shall close its contacts to initiate ventilation system when the air contamination exceeds its set point.

Chilled water reset controller shall have integral reset action to eliminate sustained system offset and be capable of receiving signals from chilled water and outdoor air sensors to control chilled water supply temperature according to an adjustable reset schedule. The controller shall have an adjustable set point for absolute high limit. Controller shall have an indicating lamp that will vary in intensity with the controller output. Controller shall be available with either proportional or 3-point floating output.

Rate/reset controller shall be of the proportional type with adjustable integral and derivative actions. The controller shall be field adjustable for either direct or reverse action and shall be supplied with a switch to eliminate the integral and derivative functions for calibration purposes. The output of the controller shall be 0-20V or 0/4 to 20mA DC. An indicating lamp shall be provided which will vary in intensity as the output varies.

Constant temperature controller shall be of the proportional type with integral reset action to eliminate sustained system offset. The controller shall have a switch for selecting long or short integral reset times. Controller shall have an indicating lamp that will vary in intensity with controller output.

C4.4.3 Control Panel

The Control Panel shall be installed in the A/C Control Room of the building at location as shown in the Contract Drawings with a sub-panel, if required, for monitoring and data logging in location as specified.

The panel shall be constructed with 1.5 mm thick hairline finished stainless steel sheets c/w all flush galvanised iron (G.I.) supports and accessories. All the lettering shall be in English and Chinese characters and to be engraved on the panel. All lettering and characters shall be approved by the Architect before fabrication. The front cover shall be of 2 mm thick hairline finished stainless steel with sectional recessed hinged cover for easy inspection and maintenance.

The panel shall include the following:

(a) Indicating lights, ammeters, gauges, control switches, push buttons, control wiring and other necessary equipment to enable remote operation and monitoring of all A/C equipment.
(b) The running and alarm indicating lights for a particular equipment shall be fitted onto the panel as standard module blocks.

(c) An alarm chime shall be provided to sound an alarm condition when any of the alarm indicating lights is energised. An alarm mute button shall also be provided to acknowledge the alarm by the operator. Alarm indicating lights shall remain on until the conditions causing the alarms are returned to normal state.

C4.4.4 ACMV Sub-System DDC Controller Resident Software Features – Energy Conversation

For full specification of the energy calculation feature of the DDC controller, refer to Sub-section C5.41.

C4.4.5 ACMV Sub-System DDC Controller Resident Software Features – Other Features

(a) Power Demand Monitoring / Load Shedding

For full specification of the power demand monitoring / load shedding feature of the DDC controller, refer to Sub-section C5.43.

(b) Optimum Start Time

For full specification of optimum start time feature of the DDC controller, refer to Sub-section C5.44.

(c) Supply Air Reset

For full specification of supply air reset feature of the DDC controller, refer to Sub-section C5.45.

(d) Chilled Water Optimisation (CHO)

For full specification of chilled water optimisation feature of the DDC controller, refer to Sub-section C5.46.

C4.4.6 DDC Sensors

All sensors specified in this Clause shall meet with the requirements in the latest Guidance Notes for Management of IAQ in Offices and Public Places and the Guide for Participation in the IAQ Certification Scheme published by HKSAR Government.

(a) Temperature Sensors

Temperature sensors shall be either of the thermister (NTC) type with a high linear resistance change versus temperature change or Platinum (PT1000) to ensure good resolution and accuracy.
Sensors shall be factory calibrated and shall be connected to remote controller by means of suitable cables.

Sensors shall not require compensation for cable length etc..

For immersion temperature sensors, sensors shall be provided with immersion pocket. The sensing range shall be of 0 °C to 120 °C.

For room / wall mounted temperature sensors, sensors shall have a connection plate to permit easy removal of the sensor during decorations etc. The sensing range shall be of 0°C to 40°C. The accuracy shall be within ±0.5%. There shall be option for temperature display in the sensors.

For ductwork type temperature sensors, sensors shall have a separate mounting flange with snap-on connection to permit sensor adjustment.

For outdoor temperature sensors, the sensing range shall be of -40 °C to 40 °C. The accuracy shall be within ±0.5%.

(b) Humidity Sensors

Humidity sensors shall be of the capacitance type with operating range of 5% to 95 % and the accuracy shall be within ±3% R.H. at 23°C. Sensors shall be suitable for use on the duty expected.

The sensors shall vary the output voltage with a change in relative humidity.

Humidity sensors shall be available for room or ductwork mounting.

Sensors shall be connected to remote controller by means of suitable cables. Sensors shall not require compensation for cable length etc.

(c) Absolute Humidity (Dew Point) Sensors

Absolute humidity (dew point) sensors shall utilise an active element to sense the actual quantity of water vapour per volume of dry air when the relative humidity is from 12 to 100 percent.

Sensors shall be highly repeatable and change resistance with a change of moisture content in the air.

Sensors shall be connected to remote controller by means of suitable cables. Sensors shall not require compensation for cable length etc.
Accuracy of the sensors shall be within ±3% R.H. at 23°C.

(d) Combined Type Humidity and Temperature Sensors

Sensors shall have elements mounted in a common enclosure and be able to be connected to remote controller by means of suitable cables.

Sensors shall not require compensation for cable length etc..

Accuracy of the sensors shall be within ±3% R.H. at 23°C for temperature and humidity control respectively.

(e) Differential Pressure Sensors

Differential pressure sensors shall vary the output voltage with a change in differential pressure.

Sensors shall be connected to the remote controller by means of suitable cables, and sensors shall not require compensation for cable length etc.

(f) Carbon Dioxide Sensors

Non-dispersive technology with sensing range of 0 to 2000 ppm shall be used for carbon dioxide sensors.

The accuracy shall be within 5%.

Carbon dioxide sensors shall be available for room or ductwork mounting.

(g) Carbon Monoxide Sensors

Carbon monoxide sensors shall be factory assembled units, designed to continuously monitor and indicate the level of carbon monoxide in parts per million on its meter and to activate the alarm circuit, alarm horn and warning light when the carbon monoxide concentration reaches the alarm point and deactivate the alarms when the carbon monoxide concentration drops below the alarm point.

The alarm point shall be factory set at 200ppm and shall be internally adjustable from 10 to 300ppm. Sensor response shall be 90% of maximum reading within 20 seconds with 200ppm carbon monoxide concentration.

The sensor coverage shall be based on the requirements of the appropriate regulations but not be less than 500m² per one sensor.

Unit shall be designed for operation with 220 V, 50Hz, single phase supply and shall have solid-state circuitry, terminal strip with contacts for recorder, alarm and fault
outputs, replaceable factory-matched pair of catalytic, semiconductor sensors, meter calibrated 0 to 300ppm, illuminated ON, PURGE, ALARM ON, FAULT/TEST switches, momentary ALARM RESET switch and an alarm horn, all mounted on the unit’s cover.

Unit shall have environment-proof, fibreglass polyester case with hinged, latched and lockable cover. Alarm light shall be mounted on the top of the case and conduit connector or opening and a test gas connector at the bottom of the case.

Sensors shall have at least a life time of 3 years with warranty certificate from the manufacturer. Replacement shall consist of replacing the detector head and filter.

Sensors shall comply with UL Standard, BS standard or other relevant regulations for gas monitoring.

(h) Nitrogen Dioxide Sensors

Nitrogen dioxide sensors shall be factory assembled units, designed to continuously monitor and indicate the level of nitrogen dioxide in parts per million on its meter.

Electrochemical type sensor with resolution of 0.1 ppm shall be used for the nitrogen dioxide sensors.

The sensing range of 0 to 20 ppm shall be used.

Unit shall have environment-proof, fibreglass polyester case with hinged, latched and lockable cover. Alarm light shall be mounted on the top of the case and conduit connector or opening and a test gas connector at the bottom of the case.

Sensors shall have at least a life time of 3 years with warranty certificate from the manufacturer. Replacement shall consist of replacing the detector head and filter.

Sensors shall be complied with UL Standard or other relevant regulations for gas monitoring.

(i) Air Velocity Sensors

Air velocity sensors shall be capable of linear indication of the velocity of air in a ductwork from 0 to 15 m/s, and shall vary its output voltage with a change in air velocity.

Sensors shall have range selection for low velocities.

Accuracy of the air velocity sensors shall be within ±1% of the range.
Sensors shall be connected to the remote controller by means of suitable cables, and sensors shall not require compensation for cable length etc.

(j) Contamination Sensors

Contamination sensors shall vary the conductivity as the degree of gas or smoke concentration changes.

The sensor shall be connected to the remote controller by means of suitable cables, and sensors shall not require compensation for cable length etc.

(k) Flow Sensors

Flow sensors shall be of the electromagnetic type.

Sensors shall be capable of measuring range suitable for the application.

Electrodes shall be of stainless steel or other approved material suitable for the liquid to be measured.

Energy saving function for external battery power supply shall be provided as required.

Complete self diagnostic function of the measurement system (sensor and converter) shall be provided;

Accuracy of the air velocity sensors shall be within ±1 % of the range.

(l) Flow Switches

Flow switches shall be electric and two-position with snap action.

Operating pressure of the switches shall conform to the requirement of the installation and shall not be less than 1000kPa.

Switches shall be adjustable for sensitivity to flow and the adjustment range shall include flow valves applicable to the equipment protected by the flow switches.

C4.4.7 Electric / Electronic Damper Actuators

For full specification of the electric / electronic damper actuator, refer to Sub-section C5.51.

C4.4.8 Control Valves

For full specification of the control valve, refer to Sub-section C5.49.
C4.4.9 Automatic Dampers

For full specification of the automatic damper, refer to Sub-section C5.50.
C5.1 CCMS ARCHITECTURAL OVERVIEW

The CCMS system shall consist of a Server with terminal, keyboard and other necessary peripherals, User/Operator Workstations if specified, router, gateway and/or interfacing unit, CCMS Sub-systems to be integrated, General Purpose Controllers, Unitary Controllers, Analog/Digital Input and Output devices such as sensors, actuators, etc. of each CCMS Sub-system interconnected via Local Area Network, Field Bus and/or Remote Communication.

CCMS Sub-systems that are required in the Particular Specification to be integrated in the CCMS shall include, but not be limited to, the followings:-

- ACMV Monitoring and Control
- Electrical System Monitoring
- Lighting Control
- Energy Conservation Programmes
- Emergency Electrical System Monitoring
- Fire Installation Monitoring
- Security Installation Monitoring
- Lift Programme Control and Monitoring
- Garage CO Monitoring and Control where required
- Mechanical Pumping and Plumbing Control and Monitoring
- Normal, Emergency and Preventive Maintenance Notification and works ordering.
- IAQ measurement where necessary

CCMS system shall comply with all the operational requirements as indicated in the drawings, specifications or point schedule.

The CCMS shall be a distributed system, any single point failure shall not impair the operation of the whole system.

Each CCMS Sub-system shall be self-contained and be able to continue to perform all Sub-system control and monitoring functions in the event of failure of the CCMS server.

Each General Purposes Controller or Unitary Controllers shall have intelligence and be able to continue to operate all local control functions in the event of failure of any higher hierarchy control systems.

C5.2 TERMINOLOGY

General Purpose Controller is a device for the regulation or management of a system or component.

Unitary Controller is a device for controlling or monitoring a single piece of equipment.
Gateway/Interfacing Unit is a device that connects two or more dissimilar networks, most likely with different communication protocols permitting information exchange between them.

C5.3 RELEVANT STANDARDS

Where applicable standards exist, the products provided shall comply with the standards etc. of the relevant authorities as stated in Section A2 of this General Specification or equivalent standard, and the list below where applicable:-

(a) American Society of Heating, Refrigeration and Air-conditioning Engineers, Inc. 135-1995 BACnet Communication Protocol for Building Automation and Control (BACnet)


(c) Echelon Corporation LonTalk® Protocol (LonTalk)

(d) Electronics Industries Association EIA 232 Interface Between Data Terminal Equipment and Data Circuit Terminating Equipment Employing Serial Binary Data Exchange.


(f) Electronics Industries Association EIA 568a Commercial Building Telecommunications Wiring Standard Category 3 (EIA 568a Cat 3)

(g) Federal Communications Commission 47 CFR Part 15 Subpart B Unintentional Radiators (FCC 47 Part B)


C5.4 MANUFACTURING STANDARDS

The system shall be built from standard packages. The estimated amount of customisations to suit the requirements of the Particular Specification shall be specified in the tender submission.

All materials and equipment used shall be standard components, regularly manufactured and not custom designed specifically for the project. All systems and components shall have been thoroughly tested and proven in actual field use for at
least 6 months and with at least 3 relevant job references locally either private sector or with government.

The CCMS shall be a fully integrated system of computer-based building automation. The system shall be modular, permitting expansion by adding hardware and software without changes in communication or processing equipment. The CCMS, while 'on-line' must be capable of adding, modifying, deleting points and inter-lock sequences without changes to 'hardware' and field wiring or control devices. These changes shall be input through various input/output devices incorporated into the CCMS.

All CCMS server and associated devices shall be able to operate properly under environmental conditions as specified in Sub-section A3.1.10. The CCMS Server and peripheral devices shall not be installed until the operating area is air conditioned and reasonably free of dust and other contaminants which could impair their operation.

All controllers’ cubicles shall be supplied factory pre-wired and terminated for connection to the field devices.

Controllers’ electronics shall be solid state, utilizing distributed processing techniques, and of the plug-in circuit board type. Separate fusing shall be provided for all control voltages.

Construction standards for panels, racks, cabinets and other equipment provided shall meet with the following minimum standards :-

(a) Racks and panels shall comply with EIA(US)RS310B or equivalent standard.

(b) Panels shall be made of steel, suitably reinforced and braced so as to provide flat-surfaced, rigid construction.

(c) Material surfaces shall be free of scale, welding slag and dirt.

(d) Panel surfaces shall be flat and free from waviness.

(e) Stiffness and bracing shall be provided as required.

(f) Handling during installation shall be such that the panels will not suffer distortion or buckling.

(g) Cutouts shall be square with consoles to ensure that the controls shall be installed level and square. Finished cutouts and holes shall be free of burrs and sharp edges and fitted with rubber grommets to prevent cable insulation damage.

**C5.5 CCMS INTER-NETWORKING STANDARD**

The CCMS Server, Workstations shall be inter-connected with Local Area Network (LAN) or remote communication. Each CCMS Sub-system shall be connected to the LAN through a gateway, router or remote communications.
The General Purposes Controller, Unitary Controller and Smart Devices of each Sub-system shall be inter-connected with field bus.

The LAN’s physical and data link layer shall comply with ISO8802.3 standard with a minimum speed of 10Mbps.

The Remote Communication’s physical layer shall comply with EIA 232 standard.

The field bus’s physical layer shall comply with EIA 485 standard with a minimum speed of 19200 bps.

The communication protocol of CCMS Server and Workstations with CCMS Sub-systems shall comply with BACnet Standard. The CCMS Server and Workstation shall conform to Class 6 Conformance Class and the gateways/router for each sub-system shall conform to Class 5 Conformance Class.

The CCMS Server and Workstations shall comply with Addendum 135a to ANSI/ASHRAE 135-1995-BACnet and support BACnet/IP.

The communication protocol of General Purposes Controllers, Unitary Controllers, Smart Devices in field bus shall comply with BACnet or LonWork standard.

All General Purposes Controllers, Unitary Controllers, Smart Devices in field bus complying with LonWork standard shall conform to the LonMark interoperability Guidelines.

All General Purposes Controllers complying with BACnet shall conform to the Class 4 Conformance Class.

All Unitary Controllers complying with BACnet shall conform to the Class 3 Conformance Class.

All Smart Actuators complying with BACnet shall conform to the Class 2 Conformance Class.

All Smart Sensors complying with BACnet shall conform to the Class 1 Conformance Class.

**C5.6 CCMS SYSTEM CONFIGURATION**

The central control monitoring system shall comprise a central and satellite control workstation, DDC outstation, DDC controller, communication network for signal/data transmission among DDC outstations/controllers and various field support hardware to form a true “Distributed Intelligence Techniques”.

**C5.7 CCMS Central Control Workstation**

The central control work station shall comprise the followings:

- Personal Computer.
- Mouse and keyboard
- 21” CRT monitor
- A3 ink/laser printer capable of handling continuous paper
- UPS capable of backup for 1 hour of operation for the PC, monitor and printer
- A 16-bit/full duplex audio system c/w speakers

C5.8 UNINTERRUPTED POWER SUPPLY

The CCMS Server, Operator Workstation and all connected peripherals shall be backed up by an Uninterrupted Power Supply (UPS) against voltage surge and spike.

In case of power failure, the UPS shall invoke alarms to all operators and supply power for more than one hour.

In the event that the unit is shut down due to prolonged power failure, all information contained within the CCMS server and workstation shall be backed up to hard disk.

Upon restoration of the power supply, the CCMS Server, Workstation and connected peripherals shall automatically restart, reloading all data including time and date automatically at high speed. No operator action shall be necessary for this process.

C5.9 PORTABLE OPERATOR TERMINAL HARDWARE

Portable operator terminal hardware shall meet with the following requirements:-

- Weight of less than 2 Kg
- Run on rechargeable battery
- Capable of retrieving and storing information to and from CCMS server and DDC controllers.
- Input method can be keyboard, touch screen, track point and/or mouse.

C5.10 DDC CONTROLLER HARDWARE

The DDC Controller shall have blinking LED’s to identify malfunction for speedy replacement without changing or undoing wiring.

Any Analog/Digital Inputs and Outputs shall be relayed or optically isolated.

The DDC Controller shall be capable of complete stand alone operation.

The firmware shall be upgradable through uploading of software.

The EPROM/Flash Ram containing the firmware shall be socketed for easy site replacement.

RAM and the clock shall be provided with power backup of 72 hours instant recharged capacitor or 12-hour trickle recharged batteries. The real time clock shall be automatically synchronised upon system recovery.
The DDC Controller shall be automatically reinitialised upon restart or power restoration.

The DDC Controller shall provide universal inputs (0-10VDC, 4-20mA, 100K Ohm, Dry Contact Closure, Voltage Level Transitions, Pulse Accumulator Inputs) capable to accept information on any point in the above form with only a programming command for differentiation between the input types. No hardware changes shall be required. The Analog Inputs shall have a resolution of 50mV or 0.08mA and a digital buffer for interrogation. The Analog to Digital conversion shall have a minimum resolution of 12 bits. The pulse accumulator input shall accept pulses at a minimum of 2 per second and up to 25 MHz.

The DDC Controller shall provide universal outputs (0-20VDC or 0-20mA), digital outputs (contact closure for momentary and maintained operation for devices) and pulse width modulation capable to give information on any point in the above form with only a programming command for differentiation between the output types. No hardware changes shall be required. Analog outputs shall have a minimum incremental resolution of one percent of the operating range of the controlled device. Output pulse width shall be selectable between 0.1 and 3200 seconds with a minimum resolution of 0.1 seconds. All contact rating shall have a minimum of 2 amps of 240VA/C. Manual/Off/Auto switch shall be provided for each digital output for temporary override control during start-up and service. An LED shall be provided to indicate the state of each digital output.

C5.11 UNITARY CONTROLLER HARDWARE

The Unitary Controller shall basically resemble the hardware of the General Purpose Controller. The processor speed shall be at least 10 MHz with a minimum of 512 Kbytes RAM.

The Unitary Controller shall have size for up to 25 points maximum.

C5.12 GATEWAY/INTERFACING HARDWARE

The Gateway/Interfacing unit shall basically resemble the hardware of the General Purpose Controller without the necessary controller’s functional components. The processor speed shall be at least 16.7 MHz with a minimum of 2 Mbytes RAM. The Gateway, which also acts as a General Purpose Controller, shall have the same Analog/Digital Input and Output points.

The Gateway/Interfacing unit shall have network connection to LAN and field bus.

The amount of data records for the hardware i.e. binary points and analog points before the memory of the DDC controller is full and start loosing data is specified in the Particular Specification.

C5.13 CCMS CENTRAL DATABASE REPOSITORY

A CCMS Central Database Repository shall reside in the CCMS Server.
The database server shall use client/server technology and comply with Microsoft
Open Database Connectivity (ODBC) latest version and support ISO SQL 89.

The central database repository shall maintain an image of the network
configuration of every device, controllers, router on the network. It shall be able to
serve installation, maintenance, monitoring and control applications by storing the
communication attributes of network variables, messages tags and other system
objects.

The central database repository shall support multiple concurrent client read/write
access, allowing installation and maintenance to proceed independently at any
number of workstations, POTs and controllers distributed around the network.

C5.14 CCMS SOFTWARE - ACCESS CONTROL

The software shall be capable of restricting any operator commands to any point at
any specified device.

There shall be a minimum of 200 System Accounts, each individually identifiable
and each changeable through keyboard entry.

There shall be a minimum of 3 access levels, defined as:-

(a) User - view all applications and acknowledge alarms, but cannot modify
database

(b) Operator - all privileges except system configuration

(c) Administrator - all configuration privileges

Operator inputs executed under valid system request shall be logged. This record
shall contain the operator command and the time and date of input execution.

The system shall automatically terminate all operator-input capability that is
previously available by valid system access after a predetermined time from the
execution of the last operator’s input requiring a valid system access request.

The system shall have a Graphic User Interface for adding, changing or deleting the
system user accounts and assigning the access levels for administrator.

C5.15 CCMS SOFTWARE - INPUT PROCESS

The operator shall be able to select applications based upon the password clearance.
Those applications not available to the operator by the password clearance shall not
be displayed.

The operator shall be able to enter memory changes through a Graphic User
Interface. The inputs shall be checked for accuracy by the CCMS system and
prompted for operator review prior to execution. Operator input assistance shall be
provided whenever a command cannot be executed because of operator input
events.
Where the command requires data such as limits, setpoint, and time, the value shall be entered in the same engineering units as the controlled variable.

A Help Mode (prompting) shall prompt the operator through each step showing the available options.

A Direct Mode shall allow the experienced operator to input, thereby executing the command with a minimum of keystrokes.

The Edit Mode shall be used for data base generation and update. Data base modification and generation shall be done while the system is on-line.

An operator input shall not inhibit change-of-state (COS) reporting.

All edit information shall be permanently stored on central database repository.

The system shall be capable of dumping and loading selected or all data base parameters (such as seasonal limits, programmed start/stop, etc.)

C5.16 CCMS SOFTWARE - INFORMATION ACCESS

The System shall be capable of attaining point status information from any designated output device with a specified access command. The point status shall consist of a point’s identification, numerical value (analog points) and associated engineering units, and individual function labels indicating that the point is locked out/unlocked, on-line/off-line, detected failure of sensor, and is in the alarm (off-normal)/normal condition.

The output following such a command shall contain the status of a single point, or all points grouped under that command.

The output following such a command shall also contain the date and the time of command execution.

C5.17 CCMS SOFTWARE - CHANGE-OF-STATE (COS) AND REPORTING

The CCMS server shall poll the points in all CCMS-Systems and detect any change in each point’s status as specified and be able to report this change-of-state to the operator.

All COS outputs shall contain a descriptor, system formatted point identity ID, point data, engineering units, and date and time.

The System shall output an alarm message, minimum 256 characters in length, for each point specified as having an alarm message or maintenance message capability in the point list. The associated message text shall be printed immediately after the standard alarm notification printout for the point.

The alarm messages shall not be restricted by word lists or any other pre-coding method. These messages shall be generated by the operator on-line, using his choice of text. Composition of any one alarm message shall not restrict the composition of any subsequent alarm message of text.
Summaries of message content and points assigned to messages shall be displayed on the operator’s terminal or printed on command.

The System shall be able to assign a system application or a user defined application to any point upon a COS detection.

The System shall have the capability of directing the COS output for a point to an operator station.

Change-of-state reporting shall be provided during the output of operator requested logs and summaries.

When multiple change-of-states are received, they shall be output and or printed chronologically.

The administrator shall be able to specify whether a change-of-state requires acknowledgement or not.

The system shall inhibit the reporting of associated analog COS upon a CCMS Sub-system shutdown. Upon restarting of the Sub-system, the analog alarm reporting for associated points shall remain inhibited for an operator predetermined time. If any of these points are still in alarm after the time delay, they shall report as specified in the point chart.

C5.18 CCMS SOFTWARE - ALARM PROCESSING AND REPORTING

C5.18.1 Alarm Scanning

The General Purpose Controllers and Unitary Controllers shall continuously scan all points connected to them and update the Central Database Repository on binary changes of state and significant analog changes. The degree of significance of an analog change necessary to require database update shall be assigned from a table in the Central Database Repository through the operator’s terminal and downloaded to the appropriate controller. The system shall compare any change of state or analog update to establish parameters and determine if the point is in an alarm condition. Alarms shall be queued for reporting and under no circumstances shall any alarm go undetected due to multiple alarms. A response time of 3 seconds (or as otherwise specified shall be provided for the period between alarm detection and reporting for typical and worst case situations)

C5.18.2 Alarm Levels

(a) General

Alarmable points shall be assigned to one of three levels. The levels shall be emergency, critical, and maintenance alarms. The assigning of alarm levels shall be accomplished at point definition and shall be able to be modified on a per-point basis at any time through the operator’s terminal.
(b) Emergency Alarm

Emergency alarms shall be printed on the alarm printer and initiate an audible alarm. The alarm shall be muted when the alarm is acknowledged. Emergency alarms shall be reprinted at a selectable time interval until corrected. The reprinting shall not re-start the audible alarm.

c) Critical Alarm

Critical alarms shall be reported in the same manner as emergency alarms except that the reprinting cycle shall stop on alarm acknowledgement.

d) Maintenance Alarm

Maintenance alarms shall be printed as described below, but shall not actuate the audible alarm. They shall not be reprinted on a periodic time increment and shall not be required to be acknowledged.

e) Returns to Normal

On return to normal, the reprinting cycle on emergency alarms shall stop. The return to normal message shall be printed for all three alarm levels.

f) Alarm Acknowledge

Alarms shall be acknowledged by entering the acknowledge command. Points in critical or emergency alarms shall be displayed in the order of detection. An alarm shall be acknowledged when an affirmative response is received from the operator.

C5.18.3 Alarm Reporting

Each individual point shall be reported on and the condition for reporting shall be determined at the time the point is defined and shall be able to be modified any time thereafter. Conditions for reporting shall be:

(a) No report under any circumstance,

(b) Reporting of alarms and returns to normal only

(c) Reporting of all change of state regardless if the state is an alarm.

(d) Alarms shall be printed or displayed in English language including descriptions of the location, system and point, the status or value, and the alarm condition (for example, high, low and so forth). The report shall also include time and date.
(e) Format of the alarm report shall be configurable through the report generator.

C5.18.4 Alarm Messages

The system shall be able to provide capability to create and assign to any point a message to be printed at the time of alarm similar to the COS alarm message.

C5.18.5 The System shall be able to assign a system application or a user defined application to any point upon an alarm detection.

C5.18.6 Alarm Recording

A minimum of the last 200 alarms or return to normal messages shall be kept in storage and displayed or printed on command. The operator shall be able to select for listing of all alarms, those alarms in a particular location, alarms in a particular system, or the alarm history of a particular point. The operator shall also be able to restrict the summary to those alarms occurring after an operator-selected time and date. The summary shall include the time and date of occurrence, the location, system and point descriptor, value or status at the time of alarm and alarm condition (for example, high, low, return to normal, etc.). The recording of alarms on specific points shall be able to be 'enabled' or 'disabled' on command. A summary of points disabled for alarm recording shall be provided.

C5.19 CCMS SOFTWARE - EVENT PROCESSING

The system shall provide a Wizard where the operator can define an event algorithm utilising multiple conditions, arithmetic logic, and Boolean logic for a particular event.

The algorithms shall consist of a minimum of up to five-level deep logical statement.

The functions that may be initiated if the conditions are met shall include, but not be limited to, the following:

- Initiate a binary command.
- Reset an analog point to a specified value.
- Reset an analog point by a specified increment or decrement.
- Change the point access control status (for example, enable, disable, lockout, off-line).
- Initiate or cancel a trend.
- Change analog alarm limits.
- Reassign the alarm reporting device.
- Print a report
- Print an operator defined message.
- Initiate a user-written programme.

The operator shall be able to display or print a summary of any event defined.
The operator shall be able 'enable' or 'disable' specific event algorithms through the operator’s terminal and request a summary of disabled algorithms.

C5.20 **CCMS SOFTWARE - SCHEDULING**

The system shall automatically initiate equipment or system commands based on a preselected time schedule for those points specified as programmable in the point list. This time schedule shall provide programme times for each day of the week (Monday through Sunday) on a per point basis.

The operator shall be capable of entering, on-line changing or deleting programme times. The programme shall have one minute resolution on-line. COS reporting shall not be inhibited while making on-line changes to programme parameters.

The System shall provide time schedules for each time programmable point unless specified otherwise.

Any point not responding to a programme function command shall automatically generate a change-of-state output as herein before defined.

An additional time programme day shall be provided for holidays. The System shall be provided with the capacity to handle a minimum of 366 consecutive holidays.

The start of a holiday programme shall be programmable up to 31 days in advance.

C5.21 **CCMS SOFTWARE - GRAPHIC DISPLAY**

The system shall provide graphic filter to import AutoCAD drawing, JPEG graphic file, Compuserve GIF graphic file, Corel Draw graphic file, Microsoft Bitmap graphic file, Microsoft PC Paintbrush graphic file, Microsoft Metafile graphic file, Lotus 1-2-3 graphic file, Adobe Photoshop graphic file, HP Graphic Language graphic file, Postscript graphic file and other common graphic formats for graphic display.

The system shall provide a series of tools which support the creation, modification, cataloguing, and subsequent display of real-time colour schematics which shall represent a process, equipment, or geographical areas.

Graphics shall be created via mouse and keyboard selection of graphic library stored symbols and system profiles. The system shall provide, in addition, the capability to create custom symbols, system profiles, floor plans, buildings, etc., and to store them in the graphic library.

The schematics shall dynamically present the current state and/or values of operator-selected field or calculated points. These status or values shall be overlaid at the appropriate location on the schematic.

When the operator calls for the colour graphics tools, a tool box shall automatically appear on the screen. The tool box shall allow the operator to select a number of commands. The commands shall include, but not be limited to, the following:
- Master Schematic Display
- Schematic Index Display
- Direct Access to Schematics by Schematic Number
- Direct Access to Schematics by Point Acronym
- Add or Change Schematics Titles and Labels
- Add or Modify Schematics
- Add or modify Real-Time Data to Schematics
- Develop New Schematic Symbols
- Return to the Operating System

The operator shall be able to select desired command by the use of the terminal keyboard or mouse.

The displaying of the master schematic shall allow the operator to use a hierarchical method to display areas of increasing scale sequentially. The master schematic shall be an overview of the entire facility. The schematic shall be broken up into zones which represent logical areas for display. The operator shall be able to select a particular zone he wishes to view. The graphic files of the selected zone shall also be able to be broken up into smaller geographical areas of larger scale. The number of hierarchical tiers shall not be limited and the hierarchical selection shall be bi-directional.

Selecting the “index to schematics” command from the tool box shall cause the first page of the schematic index to appear automatically. The index shall consist of the schematic number followed by the schematic title. The operator shall be able to select previewing the schematic in a preview window. The operator shall be able to select a schematic display, roll to the next page of the index, or exit back to the master index.

The direct access to schematics command shall allow the operator to display a schematic by entering the schematic number or by entering an acronym of a point on a schematic.

The operator shall be able to create new graphic symbols by calling using Graphical drawing tools or imported from other format graphic files.

The operator shall be able to assign real-time data to the schematics. The different types of points shall include, but not be limited to:

- Start/Stop
- Start/Stop/Auto
- Off/High/Low
- Analog Inputs
- Binary Inputs
- Calculated Points

When the schematic is displayed, real-time data shall appear on the screen automatically. The data shall include analog values with engineering units and binary statuses (on, off, open close, etc.). The status of the point shall be indicated by the colour code. Colour codes shall be as follows:

- On/Normal - Red
- Off/Normal - Green
- Disabled or Locked Out - White
- Alarm - flashing Yellow

Real-time data shall be automatically updated on the screen at least once a minute or as stated in the Particular Specification.

The operator shall be able to issue commands by utilizing the keyboard or mouse. Once a schematic is displayed, the operator shall be able to call up an individual point and a menu shall appear on the page indicating the commands available for that point. At the same time additional information on the point shall appear on the screen. This information shall include the full English language description of the selected point. Commands shall include, but not be limited to, the following:

- Start
- Stop
- Auto
- High
- Low
- Change Setpoint and Alarm Limits
- Disable
- Enable
- Lockout
- Restore
- Alarm Message Display
- Plot graph of totalized or averaged values for the last 24 hour
- Initiate Program

Only those commands applicable to the selected point type shall be displayed in the menu. The results of the command shall be displayed on the screen when updated. Commands that are not within the operator’s security range shall not be available to the operator.

The operation of the colour graphics tools shall not interfere in any way with the operation of the rest of the system.

C5.22 CCMS SOFTWARE - ERROR MESSAGES

The system shall report error messages for operator diagnostic and operation assistance.

C5.23 CCMS SOFTWARE - OPERATOR’S MESSAGES

Operators shall be able to transmit messages from one operator’s terminal to any future additional operator’s terminal. The message shall be up to 70 characters long. The message shall be able to go to all terminals or be restricted to a specific terminal.

C5.24 CCMS SOFTWARE - REPORT GENERATOR

A wizard featuring Microsoft Word processing tools for the creation of custom building reports.
Report can be of any length and shall be able to contain any points for the CCMS Sub-system.

The report generator shall have access to Arithmetic function, Boolean logic, String function, Datetime function to perform mathematical calculations inside the body of the report, control the display output of the report, or prompt the operator for additional information for the report.

C5.25 CCMS SOFTWARE - LOCKOUT SUMMARY

A lockout summary shall be provided which contains the point status of all points specified by the operator and in the locked out condition.

The system shall be capable of automatically initiating a lockout summary based on a pre-selected time schedule.

Upon operator request, the System shall output a lockout summary that shall list only those presently in the locked out condition. In addition, all logs and summaries shall display a locked out indicator for those points.

Lockout summaries shall indicate on a per-point basis the lock-unlock status of each point through the use of special characters or flags.

C5.26 CCMS SOFTWARE - ALARM SUMMARY

An alarm summary shall be provided which contains the point status of all points in the alarm condition.

The system shall be capable of automatically initiating an alarm summary based on a pre-selected time schedule.

C5.27 CCMS SOFTWARE - MESSAGE AND GRAPHIC SUMMARY

A summary shall be provided which details the contents of any and all messages within the system.

A summary shall be provided detailing the instruction listing for any and all dynamic colour graphics.

C5.28 CCMS SOFTWARE - POINT INVOLVEMENT SUMMARY

The system shall provide the capability of displaying or printing all of the routines application that a particular point is involved in. The point and display or print selection shall be input by the operator.

C5.29 CCMS SOFTWARE - SIGNAL PRIORITY

Alarm signals shall have break-in priority over all other process that may be in progress. All other processes running shall resume to normal after completion of
the alarm signal. Within the alarm level, all signals shall be successive, non-interfering in operation with break-in as defined above. All other routines shall occur on a successive non-interfering basis.

C5.30 CCMS SOFTWARE - SYSTEM LOG

A system log shall be provided which contains the point status of all points associated with each CCMS Sub-system. This system shall not be limited or restricted by any hardware grouping. All systems, therefore, shall be of software groupings only.

The CCMS server shall be capable of automatically initiating system log based on a pre-selected time schedule.

Selection Log - As designated by the operator the system shall be able to printout or display full information on the following:

- A single specified point.
- All points within a specified group.
- All points within units of a similar type.
- All points within a specified building or zone within a building.
- All points within a CCMS Sub-system.

Status Log – the system shall be able to indicate full information on a motor or other electro-mechanical or control device in the system:

- Point indication
- Contact status of the point - On-Off
- Alarm - Normal status
- Operating Mode

Trend Log – the system shall be able to provide a means of producing a printout of selected points on a periodic time basis. The operator shall also be able to trend record to a harddisk for later retrieval and print out. Points shall be capable of being added or deleted and time intervals selected through the operator terminal. Time intervals shall be able to be assigned from 1 minute to 120 minutes as a minimum. The operator shall be able to list a summary of points on trend along with the trend interval and current value or status.

C5.31 CCMS SOFTWARE - HISTORICAL PROFILES

The system shall provide the capability for the operator to build historical profiles through the operator’s terminal and initiate the profile immediately, automatically at some future specified time of day and/or automatically on a time increment. Profile shall be displayed on the operators terminal or printed as selected by the operator. Any averaged or totalized point shall be able to be assigned to a profile. Multiple profiles shall be able to be defined and multiple points assigned to a single profile. Unless otherwise indicated, minimum profile formatting shall be as follows:

- Last 12 Months, by Month or accounting period
- Last 30 Days, by Day
- Last 24 Hours, by Hour
- Last Hour, by Five Minute Intervals
- Last Ten Minutes, by Minute
- Hourly-to-Hour for Today
- Day-by-Day for Current Accounting Period
- Total/Average for Today, so far
- Total/Average for Last Accounting Period
- Total/Average for Year-to-Date
- Total/Average for Hour, so far
- Total/Average for Last Ten Minutes Only

The accounting period shall be defined by the operator through the operator’s terminal.

The operator shall be able to obtain a summary of defined profiles on the operator’s terminal or on the printer as selected by the operator.

C5.32 CCMS SOFTWARE - PREDICTOR GENERATOR

The system shall provide a wizard to extrapolate historical data. The data shall be stored in files in the following format:

- Last 12 Months, by Month
- Last 30 Days, by Day
- Last 24 Hours, by Hour
- Last Hour, by 5 Minute Increments
- Last 10 Minutes, by Minute

The operator shall be able to obtain extrapolated data up to one-half the time increment of the historical data. For example, if the operator selects historical data composed of the last hour in five-minute increments, it shall be possible to extrapolate the data up to one-half hour. The operator shall be able to request extrapolated data for any time period within the allowable time increment.

The operator shall also be able to select the degree of curve fit up to degree 4. The data shall be displayed or printed on the printer by operator request.

The data shall include the point descriptor, current value, current time and date, historical values, extrapolated value and in the case of a graphic plot request, the ordinate, abscissa and curve. The curve shall include the historical data and the extrapolated data out to the maximum. The ordinate shall be defined as a value range and the abscissa shall be scaled in proportion to the display data.

C5.33 CCMS SOFTWARE - PREVENTIVE MAINTENANCE

C5.33.1 General

The system shall provide a comprehensive preventive maintenance application which shall allow the operator to schedule preventive maintenance on any item regardless of whether the item is monitored by the CCMS.
C5.33.2 Maintenance Point Definition

The system shall allow the operator to define items to be scheduled for preventive maintenance through a graphic user interface. The definition process shall be interactive similar to the definition of monitored points. The operator shall be prompted to input the following data to define a maintenance point:

- Location of the item to be maintained
- Item description
- Task to be performed
- Maintenance point acronym consisting of building, item description and number, location, trade, service interval
- Acronym of monitored point accumulating run-time
- Maintenance remarks

C5.33.3 The data shall be displayed for verification before final definition. The operator shall be able to display on the operator’s terminal or print on the printer the defined point data. The data shall be able to be modified or deleted through the operator’s terminal at any time.

C5.33.4 The maintenance data shall be stored in the CCMS Central Database Repository.

C5.33.5 Maintenance Schedule

The system shall schedule preventive maintenance based on the last date serviced, the service interval accumulated run-time of the equipment (if applicable), and assigned priority. The system shall assign a priority level to the maintenance point when scheduled. The initial priority of the point shall be level four. On the maintenance due date the priority shall change to level three. If the point is not updated after the due date with a new last service date, within the number of days defined as the notification interval, the priority shall change to level two. If not updated by an additional notification interval the priority shall be changed to level one. If a maintenance point has an assigned run-time limit either the point shall be rescheduled on reaching the run-time limit or a choice offered to the operator to decide whether maintenance should take place immediately or on the regular calendar schedule. The option shall be selected by the operator at maintenance point definition.

C5.33.6 Service Update

The system shall provide a command to enter the new date last serviced whenever maintenance of a point is completed. The system shall request the maintenance point acronym and the date serviced. The scheduler shall then calculate a new service date.

C5.33.7 Maintenance Points Summary

The system shall provide a summary of all maintenance points within each trade category. The summary shall be able to be further restricted to building, room, service interval, equipment type, or individual point. The summary shall include all defined parameters.
C5.33.8 Maintenance Worklist

The operator shall be able to obtain on command a printed worklist for all maintenance points or for an individual trade category. The worklist shall be able to be restricted to those points due (or overdue) for maintenance or a listing of all points whether currently due or not. The operator shall also be able to restrict the list to the number of man hours available for each trade category. The available hours shall be input by the operator. The list shall include the acronym, description, current priority level, date last serviced, due date of next service, and number of days service is overdue, if any. The list shall be sorted by priority level. Points within the same area serviced by different trades, due for servicing at the same time shall be summarized separately as congruent points.

C5.34 GENERAL PURPOSE CONTROLLER SOFTWARE PROGRAMMING STANDARD

The General Purpose Controller shall have a Rapid Application Development (RAD) tool for programming of the controller. The RAD tool shall present a high-level view of the functionality available by creating a graphical programming environment into which the user may place high-level function blocks and interconnect them to create the desired system capability. The programming tools shall take this high-level representation, and transform it into application code running on the controller.

C5.35 GENERAL PURPOSE CONTROLLER SOFTWARE - INPUT/OUTPUT POINT PROCESSING

The system shall provide continuous update of input and output values and conditions. All connected points shall be updated at a minimum of one second intervals.

Analog to digital conversion, scaling and offset, correction of sensor non-linearity, sensing no response or failed sensors, and conversion of values to 32 bit floating point format shall be provided.

The system shall be able to assign proper engineering units and status condition identifiers to all analog and digital input and outputs.

Proportional Integral Derivative Feedback control for Analog Input and Output shall also be provided.

C5.36 GENERAL PURPOSE CONTROLLER SOFTWARE - DIGITAL RUN-TIME TOTALIZING

The system shall provide the capability to totalize the number of hours that any binary point in the system is in the “on” condition. The point may be a motor, etc. Every binary point shall be able to be totalized on operator assignment.
The operator shall be able to set limits associated with run-time. The system shall provide capability to have a limit with every binary point. Limits shall be set through the operator’s terminal. The system shall print an alarm when the run-time of a point reaches the run-time limit. Run-time totals and limits shall be able to be reset from the operator’s terminal on command.

The operator shall be able to list a summary of run-time totals and each associated limit, if any. The summary shall be of all binary points or restricted to a particular location, system or point. The summary shall also be able to be restricted to those points that have reached the run-time limit.

### C5.37 GENERAL PURPOSE CONTROLLER SOFTWARE - ANALOG TOTALIZING/AVERAGING

Any analog or calculated point in the system shall be able to be assigned to the totalizer and/or averager programme. The points assigned shall be totalized or averaged a minimum of once a minute. The following totals and averages for each point assigned shall be kept in storage:

- Last 12 Months, by Month
- Last 30 Days, by Day
- Last 24 Hours, by Hour
- Last Hour, by 5 Minute Increment
- Last 10 Minutes, by Minutes

### C5.38 GENERAL PURPOSE CONTROLLER SOFTWARE - TIME BASED CONTROL

Any commandable point in the system shall be able to be assigned a specific command by time of day and day(s) of week through the operator’s terminal. The number of commands per point, per day, shall be limited only by the amount of memory available in the respective controller. The following commands shall be available:

- Start
- Stop
- Auto
- Low
- High
- Change setpoint
- Change high limit
- Change low limit

Points shall be assigned time frame in which the assigned command is valid. Points shall be able to be assigned different time frame each day of the week plus a holiday schedule. A means of deleting points from the time schedule by day(s) and time frame shall be provided.

The system shall provide a time delay between start and within an individual controller, and the time delay shall be adjustable on per-point basis.
Time schedules shall be able to be downloaded from CCMS Central Database Repository to the respective controller for implementation. Loss of communication with the central computer shall not effect the operation of downloaded time schedules. Any changes made by a time schedule shall update the Central Database Repository.

The operator shall be able to list summaries of time schedules on the operator’s terminal or printer. The summary shall indicate the point and the various time windows assigned for that particular day. The summary shall be able to be restricted to a particular location, system, system type, point type, or point as well as to those days of the week desired.

A means of scheduling holidays 1 year in advance shall be provided. The system shall recognise scheduled holidays and run the holiday schedule for that day or days. The holidays shall be defined through the operator’s terminal.

A means shall be provided to extend the time of equipment operation in a particular zone. The extended time shall be initiated from the operator’s terminal or from a binary input request from the zone itself. The extension shall be for 1 day only by default and the system shall automatically use the normal schedule the next day. The zone, equipment within the zone (motors, etc.) and the length of the time extension shall be defined through the operator’s terminal. A summary of zone parameters and a summary of zones currently operating under extended time shall be provided.

C5.39 GENERAL PURPOSE CONTROLLER SOFTWARE - AUTOMATIC SEQUENCE

The system shall be a high level tool to define an automatic sequence algorithm based on occurrence of specified changes in the status of any binary, analog, or calculated point to initiate a controller’s command or a user defined programme. The following changes in status shall be able to generate an automatic sequence: -

- Change of binary status from 1 to 0 or 0 to 1
- Reaching run-time limit
- High analog alarm
- Low analog alarm
- Analog return to normal

Each input point in the system shall be able to initiate an automatic sequence and any number of points shall be able to initiate the same automatic sequence.

Points initiating user defined programme shall pass a number of parameters to the user defined programme. These parameters shall include the following:

- Acronym of the point
- Pointer to the point in the Central Database Repository
- Current status
- Last value

Automatic sequence shall be assigned to points through the operator’s terminal. Assignments shall be able to be modified at any time.
The operator shall be able to request a summary of all automatic sequences with point assignments.

**C5.40 GENERAL PURPOSE CONTROLLER SOFTWARE - GENERAL POLYNOMIAL CURVE FIT**

A programme shall be provided for polynomial curve fitting of factors up to the ninth order form with operator-entered curve coordinates. The operator shall be able to enter up to 1000 pairs of coordinates. The programme shall fit the curve defined by the coordinates to a polynomial of the order requested by the operator. The resultant parameters shall be used in polynomials in user written programmes or in the calculation programme.

**C5.41 ACMV SUB-SYSTEM GENERAL PURPOSE CONTROLLER SOFTWARE - ENERGY CALCULATION**

C5.41.1 Energy Calculation shall perform the following functions:-

(a) Air Flow Rate
   Calculate airflow rate from air flow meter or on differential pressure in supply and return ductwork.

(b) Liquid Flow
   Calculate flow rate from differential pressure across an orifice or venturi, or from an annubar sensor or Electro-magnetic flow sensor. Sensor acronym and type shall be input by the operator.

(c) Fluid Energy Rate
   Based on flow and differential temperature.

(d) Zone Cooling Energy
   Calculate total cooling energy in a zone based on supply and return air dry bulb and either wet bulb or relative humidity and the volume flow rate of the space.

(e) Electrical Power
   Calculate electrical power based on voltage and amperage, or on pulse meter input.

C5.41.2 The operator shall be able to determine the time increment for performing calculations on a resolution of 1 minute.

C5.41.3 Calculated points shall be defined through the operator’s terminal in the same manner as for sensed points with additional information requested as required. The calculated point shall appear to the operator as any real
point (with a sensor) and the operator shall be able to use the acronym of the calculated point in the same manner as a real point.

C5.42 ACMV SUB-SYSTEM GENERAL PURPOSE CONTROLLER SOFTWARE - DUTY CYCLE

The operator shall be able to assign through the operator’s terminal any controlled load in the system to the duty cycle programme and define associated parameters. Parameters shall be individually assigned per load. Parameters shall be at least as follows:-

(a) Acronym of load start/stop point.

(b) Acronym of Space temperature point that will feedback space conditions to the programme. If no space temperature point exists, this parameter shall not have to be defined.

(c) The minimum on and off times for the load required for equipment protection from damages.

(d) The beginning and ending times of the duty cycle periods. Capability of up to seven unique cycle periods per load shall be provided.

(e) The maximum allowable off time per load individually defined per period.

(f) The time resolution for cycling within each period. The resolution shall be, as a minimum, selectable on 1 minute increments between 1 and 120 minutes.

(g) The percentage 'off' time within each time resolution. The percentage shall be selected, as a minimum, on 5% increments between 5 and 95%.

(h) The commanded status of the load on a high alarm and the commanded status of the load on a low alarm of the space temperature feedback.

The operator shall be able to modify any parameter on an individual basis at any time.

Each load assigned to the duty cycle shall be cycled based on the individual parameters assigned to it. The load shall be 'off' for the percentage of time defined for each time resolution, but never for more than the maximum 'off' time for any one time. Space temperature alarm shall command the load to its defined status. In no case shall the load ever be put 'on' or 'off' for less time than the minimum 'on' or 'off' time defined.

The operator shall be able to display or print all the parameters associated with a load assigned to the duty cycler on request. Summaries shall be able to be requested for all points or restricted to a particular location or load by operator choice.
Loads shall be able to be locked out from or restored to the Duty Cycler by the operator at any time.

C5.43 ACMV SUB-SYSTEM GENERAL PURPOSE CONTROLLER SOFTWARE - POWER DEMAND MONITORING/LOAD SHEDDING

The operator shall be able to assign through the operator’s terminal on-line any controlled load in the system to the load shed programme and define associated parameters. Parameters shall be individually assigned per load. Parameters shall be at least as follows:

(a) Acronym of the load start/stop point.

(b) Acronym of the space temperature point that will feedback space conditions to the programme. If no space temperature point exists, this parameter shall not have to be defined.

(c) The minimum on and off times for the load required for equipment protection from damage.

(d) The kilowatt rating of the load.

(e) The acronym of the electric meter that the load is associated with.

(f) The priority level of the load. Providing capability of 16 priority levels.

The operator shall be able to modify any load parameter on an individual basis at any time.

The operator shall be able to display or print all of the parameters associated with a load assigned to the load shedding programme on request. Summaries shall be able to be requested for all points, or restricted to a particular location or load by operator choice.

Demand meters shall be defined by the operator through the operator’s terminal. Parameters associated with demand meters are as follows:

- Acronym of the meter.
- The demand limit to begin shedding loads.
- The demand at which loads shall begin to be restored.
- The number of priority levels associated with the meter.
- The demand interval length.

The operator shall be able to modify any meter parameters on an individual basis at any time.

The operator shall be able to display or print all parameters associated with a particular demand meter on request.

The power demand programme shall operate on a sliding window basis. Each minute shall be considered to be in the middle of the cycle interval. The demand data shall be gathered each minute. The data from the last N minutes (where N equals one-half the interval length) shall then be used to create a best fit first-degree
polynomial curve. The curve shall then be examined at what would be the end of the interval (N minutes ahead). If this value is greater than the shed limit, the power demand programme shall calculate the excess load and initiate load shedding. The shedding shall begin with the lowest priority loads and shall be governed by the point’s minimum 'on' time, maximum 'off' time, point disability, and status of the space temperature point (if one has been defined). If the point has not satisfied (continuously) its minimum 'on' time, if the maximum 'off' time has already been reached, if the point is disabled, or if the space temperature point is in alarm, the load initially shall not be shed. If the power demand programme finds that it has examined all loads in all priorities and more shedding is still necessary, according to the predicted load, it shall go back to the lowest level and re-examine the points, this time overlooking the maximum 'off' time criteria. If the power demand programme finds itself again not able to adequately shed enough load to prevent the predicted power peak, it shall again go through the loads in order of priority and disregard the status of space temperature points. If it is still unable to adequately reduce the load level, the operator shall be informed of the number of kilowatts still needed to be shed. Under no circumstances shall the system shed a load if the points minimum 'on' time has not been reached or if the points is disabled.

If at any time after load shedding has been initiated, the system forecasts the end of cycle consumption to be below the restore limit, the power demand programme shall begin starting up the loads in order to bring the system back into the state in which it was operating before the shedding began. Load restoration shall be performed in reverse order from that observed in the shedding process. The first group of points to be restored shall consist of those whose sample area is in alarm. The second group shall be the remainder of the power demand monitored points that are currently 'off' and have met their minimum 'off' time. Under no circumstances shall the power demand programme restore a point that is either disabled or has not yet satisfied its minimum 'off' time. The starts shall be performed in an efficient manner, each being delayed by the amount of time specified by the preceding point within the same controller. When enough load has been restored so that the forecasted consumption is above the restore limit, the power demand programme shall discontinue the restoration process.

Points that are both duty cycled and power demand monitored may be shed by the power demand programme, but shall only be started up by the duty cycler. If the duty cycler deems it necessary to start such a point, it shall determine whether the point is off due to load shedding or normal cycling. If the point was shed and an entire power demand programme interval has not elapsed since the time of the shed, the duty cycler shall then locate and shed enough other load to allow the original point to be started, without affecting the total system power consumption.

A power demand profile shall be available to the operator upon request. The profile shall be displayed or printed by operator selection. The profile shall include the demand meter description, the time, date, demand limit, restore limit, interval length, current demand, highest demand today and time of occurrence, highest demand yesterday and time of occurrence, highest demand during current building period with time and date of occurrence, and the highest demand for the last 11 billing periods by billing period with time and date of occurrence. Billing periods shall be able to be defined by the operator through the operator’s terminal.
The optimum start programme shall calculate the latest start time for air handling units in each operator-defined zone. The calculations shall consider occupancy time, outdoor temperature, indoor temperature, desired indoor temperature at occupancy, and the capacity of the air handlers.

The programme shall run at a reschedule interval of no more than five minutes before the start-up time for all of the optimum start zones. The programme shall examine each zone at the frequency defined for that zone.

When the programme determines that the optimum start time has been reached, it shall start all of the air handling units included in the zone definition.

At the zone occupancy time, the system shall record the actual zone temperature and any deviation from desired temperature. If any unit within the zone was found to have been off-line between the start-up time and the occupancy time, the data shall be flagged as invalid.

Optimum start zones shall be defined by the operator through the operator’s terminal. Parameters shall include as a minimum the following:

- Occupancy time for each day of the week.
- Desired temperature at occupancy.
- Acronym of outdoor temperature sensor.
- Acronym of indoor temperature sensor.
- Acronyms of air handlers to be started.
- Acronym of the zone.

The operator shall be able to modify the parameters at any time. A summary of the zone parameters shall be available on command. The summary shall be displayed on the operator’s terminal or printed on the printer. The summary shall be of all zones or an individual zone.

An optimum start performance summary shall be available to the operator on request. The summary shall be able to be displayed on the operator’s terminal or printed on the printer. This summary shall detail the conditions presented to the optimum start programme as well as the results of the optimum start function for one week. The information, output by zone, shall include the difference between the target temperature and both the inside and outside air temperatures at the zone start time, the difference between the target temperature and the actual room temperature at occupancy time, and the start time measured in minutes before occupancy. Performance summaries shall be able to be requested for individual or multiple zones.

The SAR programme shall monitor status and adjust the supply air temperature set point, and shall ensure that space temperature conditions are maintained and that the space relative humidity upper limit is not exceeded. The system operator shall be able to define, modify and delete the following parameters:
- Areas to be enabled/disabled for SAR.
- High and low rest limits.
- Sampled time interval.

A log shall be provided detailing each parameter associated with supply air reset area.

C5.46 ACMV SUB-SYSTEM GENERAL PURPOSE CONTROLLER SOFTWARE
- CHILLED WATER OPTIMIZATION (CHO)

C5.46.1 The automation system shall include a software programme to perform chilled water reset, soft loading and chiller sequence. The CHO programme shall optimize the use of chilled water in either one of the two ways - the chilled water supply reset shall be based on either maintaining a constant return temperature or supply sufficient cooling to satisfy zone requirements.

(a) When the CHO programme is based on maintaining a constant chilled water return temperature, the software shall incrementally adjust the supply water set point to achieve the desired space conditions. It shall be possible to individually monitor and control each chilled water loop.

(b) When the CHO programme is based on supplying sufficient cooling to satisfy zone requirements, the software shall incrementally adjust the chilled water set point upwards until at least one zone is requiring additional cooling.

The system operator shall be able to define, modify and delete the following parameters: -

- Loops to be enabled/disabled for CHO
- High and low reset limits
- Incremental adjustment magnitude
- Sampled time interval
- Sequence patterns based on building load in kW

A log shall be provided detailing each parameter associated with a chilled water optimization loop.

C5.47 ACMV SUB-SYSTEM UNITARY CONTROLLERS

Temperature/humidity/pressure controllers shall be of the plug-in proportional type with integrated circuits. Controllers shall be capable of having up to three separate outputs. Each shall have separate zero and proportional band adjustments. Indicating lamps shall be provided for each output which will vary in intensity to indicate the amount of output. Controllers shall be available with either 0 to 20V DC proportional output, two-position output, or any combination. Controller shall have internal switches for each output to change the output signal to either direct or reverse. Controller shall be available with integral electronic circuit for absolute high or low limit control.
Air contamination controllers shall be available in one or two stages. Controller shall close its contacts to initiate ventilation system when the air contamination exceeds its set point.

Chilled water reset controller shall have integral reset action to eliminate sustained system offset and be capable of receiving signals from chilled water and outdoor air sensors to control chilled water supply temperature according to an adjustable reset schedule. The controller shall have an adjustable setpoint for absolute high limit. Controller shall have an indicating lamp that will vary in intensity with the controller output. Controller shall be available with either proportional or 3-point floating output.

Rate/reset controller shall be of the proportional type with adjustable integral and derivative actions. The controller shall be field-adjustable for either direct or reverse action and shall be supplied with a switch to eliminate the integral and derivative functions for calibration purposes. The output of the controller shall be 0-20V DC. An indicating lamp shall be provided which will vary in intensity as the output varies.

Constant temperature controller shall be of the proportional type with integral reset action to eliminate sustained system offset. The controller shall have a switch for selecting long or short integral reset times. Controller shall have an indicating lamp that will vary in intensity with controller output.

C5.48 ACMV SUB-SYSTEM FIELD DEVICE - SENSORS

C5.48.1 Temperature Sensors

Temperature sensors shall be the same as specified in Sub-section C4.4.6(a) of this General Specification.

C5.48.2 Humidity Sensors

Humidity sensors shall be the same as specified in Sub-section C4.4.6(b) of this General Specification.

C5.48.3 Absolute Humidity (Dew Point) Sensors

Absolute humidity (dew point) sensors shall be the same as specified in Sub-section C4.4.6(c) of this General Specification.

C5.48.4 Combined Type Humidity and Temperature Sensors

Combined type humidity and temperature sensors shall be the same as specified in Sub-section C4.4.6(d) of this General Specification.

C5.48.5 Differential Pressure Sensors

Differential pressure sensors shall be the same as specified in Sub-section C4.4.6(e) of this General Specification.

C5.48.6 Air Velocity Sensors
Air velocity sensor shall be the same as specified in Sub-section C4.4.6(i) of this General Specification.

C5.48.7 Contamination Sensors

Contamination sensors shall be the same as specified in Sub-section C4.4.6(j) of this General Specification.

C5.48.9 Flow Sensors

Flow sensors shall be the same as specified in Sub-section C4.4.6(k) of this General Specification.

C5.49 ACMV SUB-SYSTEM FIELD DEVICE - CONTROL VALVES

Valves used in conjunction with a CCMS for control of chilled water shall be of the modulating type with a turn down ratio of at least 50 to 1. Valve bodies shall be cast gunmetal, brass cast iron or as otherwise indicated. Seat and inner valve material shall be brass, stainless steel or as otherwise indicated. Valve sizes 50 mm and smaller shall be screwed and supplied with union fittings. Valve sizes 65 mm and larger shall be flanged. Valves shall be of the straight-through type as required by the sequence or shown on the drawings. Valves actuator shall be equipped with manual opener to allow manual positioning of valve in the absence of control power. Valves shall have authority of at least 0.5 (50%) and shall have suitable actuator to close against full pump head. Valve body shall be rated for differential pressure stroke <20 mm.

For valves used for fan coil unit, valve body and seat body shall be bronze. The inner valve and stem material shall be stainless steel. The valve shall be of the 2-way type have authority of 0.5 (50%), with body rated for differential pressure, actuator closed against full pump head, and stroke <5 mm.

Valves shall otherwise comply with Sections B9 & C9 of this General Specification.

Valves schedules for all valves modulations/on-off shall be submitted detailing the maximum allowed and actual pressure drops, authority, turndown ratio, max. pressure the actuator will close against and other valve data.

C5.50 ACMV SUB-SYSTEM FIELD DEVICE - AUTOMATIC DAMPERS

Automatic operated dampers for application in conjunction with a CCMS shall have frames of a minimum of 3.5 mm galvanised steel not less than 50 mm in width and aerodynamically formed blades of not less than 1.5 mm galvanised steel sheet. Dampers shall be adequately braced to form a rigid assembly. No damper shall have blades more than 200 mm wide. Length of blades shall be not more than 1220 mm. Blades shall be secured to 13 mm diameter zinc plated axles by zinc plated bolts and nuts. All blade bearings shall be nylon or bronze. Teflon coated thrust bearings shall be provided at each end of every blade to minimize torque requirements and insure smooth operation. All blade linkage hardware shall be constructed of corrosion resistant, zinc plated steel and brass.
For all dampers incorporated as part of a CCMS controlled systems, the control damper manufacturer shall submit leakage and flow characteristics plus a size schedule for all controlled dampers.

Supply and exhaust dampers for building systems incorporating a CCMS shall be of the low leakage types and shall be generally as described below.

C5.50.1 Standard Applications

Dampers shall be of the parallel or opposed blade design (as selected by the manufacturer’s application techniques) with replaceable butyl, spring stainless steel or closed cell neoprene edging. (Reference shall also be made to Section C2 of this General Specification where relevant.)

C5.50.2 Low Leakage Applications (Intake, Exhaust & Recirculation Dampers)

Dampers shall be of the parallel or opposed blade design (as selected by the manufacturer’s application techniques). Frames and blades shall be of 3 mm extruded aluminium. Blades shall be of the single unit 'Pin-Lock' design, 150 mm wide, with the 'Pin-Lock' an integral section within the blade centre axis. Frames shall be of 100 mm extruded aluminium channel and angle, with reinforcing bosses and groove inserts for vinyl seals. Minimum size dampers shall have 50 mm by 15 mm aluminium frames. Pivot rods shall be of 13 mm diameter extruded aluminium, 'Pin-Lock' design interlocking into blade section. Bearings shall be of the “Double-Sealed” type with Celcon inner bearing on rod riding in Merlon Polycarbonate outer bearing inserted in frame so that outer bearing cannot rotate (no metal-to-metal or metal-to-bearing riding surfaces). Blade linkage hardware shall be installed out of air stream. All hardware shall be of non-corrosive reinforced material or cadmium plated. Interconnecting linkage shall have separate Celcon bearing to eliminate friction in linkage. Dampers shall be of the overlap design with extruded vinyl seals in both frames and blades for minimum air leakage. All dampers in excess of 1 m² free area shall have reinforced corners. Curves shall be based on a velocity of 10 m/s. Opposed blade dampers shall have less than 1/2 of 1% leakage at 0.5 kPa static pressure. Parallel blade dampers shall have less than 1% leakage at 0.5 kPa static pressure. Paralled blade dampers shall have less than 1% leakage at 0.5 kPa static pressure.

C5.50.3 Two-Position control Dampers

Dampers shall be sized for minimum pressure drop at the indicated ductwork size.

C5.50.4 Modulating and Proportioning Dampers

Dampers shall be sized for an effective linear air flow control characteristic within the angle of rotation and maximum pressure drops specified.

C5.50.4 Dampers at Louvres
Dampers located immediately adjacent to intake and exhaust louvres shall be furnished in sizes as indicated because of reduced free area at louvres.

C5.50.6 Isolation Dampers

Dampers shall provide tight shut-off with negligible leakage, and shall withstand the applied pressure, velocities and turbulence in the open position.

C5.50.7 Fire and Smoke Dampers

Fire and Smoke Dampers shall meet all requirements of NFPA 90A and shall where indicated bear the 2 hour UL Fire Damper Label. Dampers shall be of the all metal, low leakage construction, with metal-to-metal seals at blades and frame, designed to operate automatically as specified in Section C2.

C5.51 ACMV SUB-SYSTEM FIELD DEVICE - DAMPER ACTUATOR

Actuators shall be of the linear or rotary type for either modulating or two-positioning control. Actuators shall have a manual opener for power failure. Control voltage shall be either 24V DC or 220V AC as required by the application, product of clutch, micro-switch shall not be accepted.

C5.52 ACMV SUB-SYSTEM FIELD DEVICE - CARBON MONOXIDE MONITOR/ALARM SENSORS

Carbon monoxide sensors shall be the same as specified in Sub-section C4.4.6(g) of this General Specification.

C5.53 ACMV SUB-SYSTEM FIELD DEVICE - CARBON DIOXIDE SENSORS

Carbon dioxide sensors shall be the same as specified in Sub-section C4.4.6(f) of this General Specification.

C5.54 ACMV SUB-SYSTEM FIELD DEVICE – NITROGEN DIOXIDE SENSORS

Nitrogen dioxide sensors shall be the same as specified in Sub-section C4.4.6(h) of this General Specification.

C5.55 ACMV CCMS SUB-SYSTEM FIELD DEVICE - VAV BOX CONTROL

C5.55.1 Fan Powered

Unless otherwise specified, a stand-alone control system shall be provided to individually control each fan powered box as a pressure independent system.
C5.55.2 Electronic controls consisting of sensors, microprocessor controller and damper actuator shall be factory mounted. Room sensor shall be field mounted.

C5.55.3 Each box controller shall communicate individually with the central processing unit. Should any part or all of the central energy management system experience downtime, each and all of the boxes shall maintain room control. Setpoint of room control shall reside within the individual room controller.

C5.55.4 Two-way communication to the CCMS Server shall be provided for setting the following functions:-

(a) Fan operating point - resetable from Server
(b) Cooling Setpoint - Resetable from central processing unit
(c) Room Temperature
(d) Supply ductwork velocity
(e) Minimum velocity setting - Resetable from Server
(f) Maximum velocity setting - Resetable from Server
(g) Night setback command - Resetable from Server
(h) Damper position

C5.55.5 Non-Fan Powered

Similar to above.

C5.56 OTHER CCMS SUB-SYSTEM

The equipment listed below shall be monitored for operation conditions at intervals not to exceed 30 seconds. However the typical equipment to be supervised and the actual requirements are indicated in the Particular Specification :-

(a) Emergency Generator : On-Off, Fail to Start, Trouble.
(b) Sprinkler Valve : Open-Closed.
(c) Fire Pumps : Unit On-Off, Fail to Start, Trouble.
(d) Domestic Water Pressure : Normal or Low.
(e) Lift or Escalator Failures

C5.57 SCHEDULE OF FUNCTION FOR CCMS

Schedule of Functions monitored and / or controlled by CCMS shall be as follows:-

C5.57.1 Chiller/Heating Water Circuit

(a) Chilled/Heating water supply temperature
(b) Chilled/Heating water return temperature
(c) Chilled/Heating water flowrate in each main circuit (normal hour, 24 hrs.)
(d) Chiller/Heating water circuit supply/return pressure
(e) Building cooling demand (chilled water flowrate, supply temperature, return temperature)
(f) Energy demand of each floor (chilled water flowrate, supply temperature, return temperature)
(g) On/off status of all motorised on/off valves
(h) External enthalpy

C5.57.2 Chiller

(a) On/off status
(b) On/off control
(c) Trip status
(d) Open/close status of on/off control valve
(e) Operating current
(f) Power input (kWh)
(g) Water failure alarm
(h) Evaporator pressure
(i) Condenser pressure
(j) Chilled water inlet/outlet temperature
(k) Heating water inlet/outlet temperature
(l) Condenser water flow rate
(m) Chiller water flowrate
(n) Chilled water setpoint
(o) On/off status of each condenser fan
(p) Trip/fault alarm of each condenser fan
(q) Local/CCMS selector status
(r) Cooling capacity (chilled water flowrate, supply temperature, return temperature)
(s) Heating capacity for heat recovery chillers (heating water flowrate, supply temperature, return temperature)
(t) Chiller efficiency (cooling capacity/power input)
(u) Refrigeration leakage alarms (2 stage)
(v) All safety alarms

C5.57.3 Primary/Secondary chilled water pump, sea water pump, heating water pump

(a) On/off status
(b) On/off control
(c) Trip/fault status
(d) Supply/return pressure
(e) flowrate
(f) Supply/return temperature
(g) 3-phase operating currents
(h) Power input (kWh)
(i) Water failure alarm
(j) Local/CCMS selector status
(k) For pump with frequency inverter :
   - Frequency inverter running
   - Frequency inverter fault
   - Motor speed
   - Frequency inverter speed control
   - Frequency inverter local/CCMS status
C5.57.4 Motor Control Centre (MCC)

(a) 3 phase voltage, 3 phase + N current, p.f., and kWh of each incoming cable
(b) 3 phase voltage, 3 phase + N current and kWh of each outgoing cable to each chiller, chilled water pumps, heating water pumps, control circuit.
(c) ON/OFF and trip status of each incoming or outgoing or interlocking ACB
(d) Battery charger failure alarm

C5.57.5 AHU, PAU

(a) Supply/return air fan On/off status
(b) Supply/return air fan On/off control
(c) Trip/fault status
(d) Local/CCMS status
(e) Filter clog alarm
(f) Supply air temperature
(g) Return air temperature
(h) Ductwork status pressure for control of fan speed
(i) Fresh air flowrate
(j) Outdoor temperature
(k) Chilled water valve control
(l) Chilled water valve position
(m) Heating water valve control
(n) Heating water valve position
(o) Return air damper control
(p) Return air damper position
(q) Fresh air damper control
(u) Fresh air damper position
(v) Loss of air flow alarm
(w) Fire trip alarm
(x) Power input
(y) CO\textsubscript{2} concentration for demand control
(z) For AHU/PAU with frequency inverter:
   - Frequency inverter running
   - Frequency inverter fault
   - Motor speed
   - Frequency inverter speed control
   - Frequency inverter local/CCMS status

C5.57.6 Ventilation fan

(a) Fan On/off status
(b) Fan Trip/fault status
(c) Local/CCMS status
(d) Damper control
(e) Damper position
(f) Filter clog (if any)
(g) CO level (for carpark exhaust)
(h) Loss of air flow alarm
(i) Fire trip alarm
(j) Power input
(k) For fan with frequency inverter:
- Frequency inverter running
- Frequency inverter fault
- Motor speed
- Frequency inverter speed control
- Frequency inverter local/CCMS status

C5.57.7 VAV/CAV boxes

(a) Room temperature
(b) Room temperature setpoint
(c) PIR sensor
(d) Air flowrate
(e) Heating water valve (if any) modulating control
(f) Damper position control/monitoring
(g) Time schedule by real-time clock w/battery

C5.57.8 FCU

(a) On/off control of each FCU
(b) Room temperature
(c) Room temperature setpoint
(d) Chilled water valve modulating control
(e) Heating water valve (if any) modulating control
(f) Ductwork heater (if any) stage control
(g) 3-position fan speed
(h) filter clog alarm
(i) Power input of group of FCU (department basis)

C5.57.9 Computer AHU

(a) On/off control and status
(b) Trip/fault status
(c) Local/CCMS status
(d) Room temperature
(e) Room humidity
(f) Room temperature setpoint
(g) Room humidity setpoint
(h) Chilled water valve modulating control
(i) Heating water valve (if any) modulating control
(j) Ductwork heater (if any) stage control
(k) filter clog alarm
(l) Loss of air flow alarm
(m) Fire trip alarm
(n) Power input

C5.57.10 Gas tight damper, fire damper, smoke/fire damper

(a) Closure alarm

C5.57.11 Chilled water/heating water F&E (closed type)

(a) High level alarm
(b) Low level alarm
(c) Pump fault/trip status

C5.57.12 Water treatment

(a) On/off status
(b) Trip/fault status

C5.57.13 Room Condition Monitoring for critical rooms, such as computer room, network room, PBX room, etc.

(a) High temperature alarm
(b) High humidity alarm

C5.57.14 Cooling Energy Monitoring

(a) Energy meters reading. The energy meters shall be located at the main tee-off at each floor for both normal and 24-hours CHW system.

C5.58 CABLE TYPE AND APPLICATIONS

Table C5.58  Cable type and applications

<table>
<thead>
<tr>
<th>Type</th>
<th>Application</th>
<th>Product Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Capacitance</td>
<td>Computer Cable for RS232; RS422</td>
<td>Tinned Copper, Datalene insulated, twisted pairs, Overall Beldfoil aluminium-polyester shield, 24AWG stranded tinned copper drain wire. Chrome PVC jacket, drain wire.</td>
</tr>
<tr>
<td>Shield Twist Pair</td>
<td>Computer Cable for LAN-BACnet</td>
<td>Tinned Copper braid, foam polyethylene insulation core, 96% shield coverage 13.4 ohm/km. Black or white PVC jacket.</td>
</tr>
<tr>
<td>Multi-mode 62.5/125 fiber</td>
<td>For LAN &amp; computer communication comply EIT/TIA 568 &amp; ISO/IEC11801</td>
<td>Multi-mode (62.5/125 micron meter) Central loose tube, LSOH, 4 core</td>
</tr>
</tbody>
</table>
SECTION C6
CENTRAL REFRIGERATION/CHILLER, DIRECT EXPANSION
EVAPORATOR AND HEAT REJECTION PLANT

C6.1 GENERAL

The refrigeration plant for air conditioning purposes shall generally be of the mechanical, vapour compression type using environmental friendly refrigerants.

The refrigeration chillers shall be factory assembled and tested complete ‘packaged’ units which may have reciprocating, centrifugal or screw type compressors and as specified in the Particular Specification or as proposed by the Contractor.

The plant shall include any accessories necessary to ensure continuous and reliable automatic operation and remote monitoring and control.

Each unit shall be capable of running continuously at the lowest step of cooling or heating capacity provided without any adverse effect.

Compressor and motor speeds shall not exceed 50 revolutions per second for reciprocating type and for screw type. For centrifugal type, the motor speed shall not exceed 50 revolutions per second and the compressor speed shall not exceed 200 revolutions per second. Energy efficient motor to optimise the system coefficient of performance will be required. If higher compressor speed is specified or allowed in the Particular Specification, the refrigeration machine shall be properly treated with factory-built acoustic silencer to limit the sound pressure level without de-rating the machine efficiency and capacity as specified in the Particular Specification.

Each compressor shall form a separate independent oil circuit with its own oil separator, oil filter and positive lubrication oil safety control circuit equipped to ensure proper functioning of each compressor and accessories.

All units shall comply, where applicable, with the following codes: ISO 1662; ANSI B9-1 Safety Code; ARI Standard 50/590-98 Testing and Ratings; VDE Electrical and Wiring Regulations for Earthing; IEE Wiring Regulations.

Characteristic curves shall show the energy consumption in kilowatts, pressure drop through the evaporator, chilled or hot water flow rates and temperatures, condenser fan speeds, etc., for each unit at 15%, 25%, 50%, 75% and 100% of full capacity.

Sound power characteristic curves shall be in dB measured in accordance with ARI standard 575 for 15%, 25%, 50%, 75% and 100% of full capacity.

C6.2 ABSORPTION UNITS

Absorption refrigeration units if required will be fully specified in the Particular Specification. They are not commonly used for general refrigeration applications in
place of conventional reciprocating, centrifugal or screw types in Hong Kong due to its less favourable energy performance.

C6.3 COLD STORAGE REFRIGERATION

Independent refrigeration circuits shall be supplied and installed at the cold storage room and shall comprise an air-cooled refrigeration system with semi-hermetic reciprocating compressor connected to each room unit cooler. The unit cooler shall be of the ceiling type, drawn through direct expansion with distributor, heat exchanger for better efficiency, and electric defrost heaters. Requirements for cold storage facilities will be fully detailed in the Particular Specification for specific application.

C6.4 COMPRESSORS, RECIPROCATING TYPE

C6.4.1 Hermetic compressors will be acceptable where either:

(a) The entire refrigeration system is completed and charged with refrigerant at the manufacturer’s works or,

(b) The condensing unit incorporating the hermetic compressor has a hold charge of refrigerant or inert gas on arrival at site.

C6.4.2 Crankshafts or eccentric shafts of all open or semi-hermetic compressors shall be balanced and, if having an input power greater than 2.25 kW, run in replaceable bearings.

C6.4.3 Pistons greater than 50 mm diameter shall be fitted with either:

(a) Compression and/or oil control rings or,

(b) A combination of compression rings and a piston ring specially shaped to act as an oil scraper.

C6.4.4 All open and semi-hermetic compressors having an input power in excess of 350 kW shall have:

(a) Removable cylinder liners

(b) Side or end covers which will enable servicing or repair of the unit to be carried out 'in-situ'

C6.4.5 Open type compressors shall have a rotary mechanical seal fitted to the driving shaft which effectively prevents leakage of refrigerant or oil. Direct coupled type units shall be driven through a flexible coupling units. Compressors with an input power greater than 25.0 kW shall be of a type which will enable the shaft seal to be removed without moving compressor or motor.

C6.4.6 Open and semi-hermetic compressors of 6.0 kW input power and above shall have:
(a) A crankshaft driven oil pump used to force feed lubricant via a strainer to the main and big end bearings and the shaft seal.

(b) An oil pressure relief valve or bleed device provided between the oil pump discharge and the crankcase.

(c) Provision for draining oil from the suction manifold into the crankcase and for venting refrigerant gas (but not oil) in the opposite direction.

(d) A crankcase heater arranged to operate while the compressor is at rest.

C6.4.7 All types of compressor, with the exception of hermetic units or factory sealed systems, shall have the following fittings provided and connected:-

(a) Stop valves on refrigerant suction and discharge connections.

(b) Refrigerant pressure gauges, not less than 75 mm diameter and fitted with means of isolation, on suction and discharge. Gauges shall have pressure and saturation temperature scales for the refrigerant being used. Alternatively, gauges with pressure scale only may be used in conjunction with a pressure/saturation temperature conversion table fixed nearby.

(c) Oil pressure gauge, not less than 75 mm diameter, with means of isolation (compressors with oil pump only).

(d) Crankcase oil level sight glass.

(e) High and low refrigerant pressure safety cutouts with adjustable differential setpoint. Settings of the protection shall be preset at the manufacturer’s recommended settings by the manufacturer at factory.

(f) Low oil pressure safety cut-out with hand reset (compressors with oil pump only).

(g) Suction refrigerant strainer.

(h) All instruments shall be mounted in a neat instrument panel mounted on the package unit or on a varnished teak frame mounted panel near to the machine being served and to a design acceptable to the Architect.

Alternatively, pressure measurements read from the display panel of the chiller is acceptable.
C6.4.8 All compressors having a refrigeration duty in excess of 35 kW shall have capacity control by means of cylinder unloading. Compressors shall be arranged so that they start unloaded.

The hot gas by-pass or injection system of capacity control will not be accepted.

C6.5 COMPRESSORS, CENTRIFUGAL TYPE

C6.5.1 Open type centrifugal compressors shall have a rotary seal fitted to the driving shaft which effectively prevents leakage of refrigerant or oil. Open compressors shall be driven through a flexible coupling of a type which enables the shaft seal to be removed without moving the compressor or motor.

C6.5.2 The lubrication system shall be arranged with an interlock to ensure adequate oil pressure at all bearings before the compressor starts and during the 'coast down' period. A replaceable or cleanable filter shall be positioned in the oil delivery pipe. Where an oil cooler is used, it shall be thermostatically controlled. A hand reset pressure or flow switch shall stop the compressor on a lubrication system failure. The oil sump shall have a thermostatically controlled electric heater which operates while the compressor is at rest.

C6.5.3 The compressor shall have automatic capacity regulation which will control at any point from 30% to 100% of full duty without inducing a surge condition. The compressor shall always start in the unloaded condition.

The hot gas by-pass or injection system of capacity control will not be accepted.

C6.5.4 The motor of a semi-hermetic compressor which is refrigerant gas cooled shall have in-built protection against inadequate cooling.

C6.5.5 The following fittings shall be provided and connected:-

(a) Refrigerant pressure gauges as Sub-section C6.4.7(b).
(b) Oil pressure gauge as Sub-section C6.4.7(c).
(c) Oil sump or reserve level sight glass.
(d) Pressure safety cut-outs as Sub-section C6.4.7(e).
(e) Low oil pressure or flow switch with hand reset.
(f) High oil temperature cut-out with hand reset.
(g) Instrument mounting as Sub-section C6.4.7(h).
(h) Stop valve on refrigerant discharge and suction.
Alternatively, pressure measurements read from the display panel of the chiller is acceptable.

C6.6 COMPRESSORS, SCREW TYPE

C6.6.1 Screw compressors shall have quiet operation with oil injection lubrication system. Open compressors shall have a rotary seal fitted to the driving shaft which effectively prevents leakage of refrigerant or oil. Open compressors shall be driven through a flexible coupling of a type which enables the shaft seal to be removed without moving compressor or motor.

C6.6.2 A device shall be fitted to prevent the pressure differential across the compressor causing backward rotation at a normal or emergency stop.

C6.6.3 The lubrication system shall be arranged with an interlock to ensure adequate oil pressure at all bearings before the compressor starts. A hand reset pressure or flow switch for stopping the compressor shall be fitted at a appropriate location from the oil pump delivery pipe to the oil sump. A replaceable or thermostatically controlled oil cooler shall be used to remove the heat gained by the oil in the rotor chamber or the chiller manufacturer shall select and confirm that the lubrication oil used can be operated at a temperature higher than the rotor chamber. The oil sump shall have a thermostatically controlled electric heater which operates while the compressor is at rest.

C6.6.4 The compressor shall have automatic capacity control equipment which will control at any point between 10% and 100% of full duty via control of the compressor speed by variable speed drive or slide valve. For compressor with stepped capacity loader control, each chiller shall have capacity control steps as specified in Particular Specification and the minimum step capacity shall be maximum 20% of full load. The compressor shall be fitted with a device which ensures that it cannot start unless in the fully unloaded condition.

Except where indicated in the Particular Specification, the hot gas bypass or injection system of capacity control will not be accepted.

The motor of a semi-hermetic compressor which is refrigerant gas cooled shall have in-built protection against inadequate cooling.

The following fittings shall be provided and connected:-

(a) Stop valves on refrigerant discharge and suction.

(b) Refrigerant pressure gauges as Sub-section C6.4.7(b).

(c) Oil pressure gauge as Sub-section C6.4.7(c).

(d) Oil sum or reservoir level sight glass.
Section C6

(e) Pressure safety cut-outs as Sub-section C6.4.7(e).

(f) Low oil pressure or flow switch with hand reset.

(g) High oil temperature cut-out with hand reset.

(h) Instrument mounting as Sub-section C6.4.7(h).

Alternatively, pressure measurements read from the display of the chiller is acceptable.

C6.6.5 Screw compressor for ammonia chiller

(a) The casing of screw compressor for ammonia chiller shall be designed to maximize strength to weight ratio and properly gasketed to prevent leakage. The compressor shall be designed for a maximum allowable working pressure higher than 2600 kPa. Suction filter and oil filter shall be provided. A check valve shall be provided at the suction side to prevent the counter rotation due to pressure equalization.

(b) The screw compressor unit shall be complete with a variable volume ratio pressure equalization device to maintain the highest efficiency under all working conditions on both the evaporator load side and the condenser cooling medium side. Control shall take place in two stages high and low volume ratio. The device shall consist of one control and one regulating piston. The unit is connected to the compressor high, intermediate and low pressure systems. These pressures act on different surfaces of the control piston and according to the internal ratio between the pressures the piston will open or close the flow of high pressure oil to the regulating piston. When the high pressure oil acts on this piston, it partly closes the compressor discharge port, which produces a high volume ratio. When the high pressure oil is drained, the reverse actions apply and the regulating piston opens part of the discharge port, giving a low volume ratio.

C6.7 CONDENSERS, SHELL AND TUBE (FRESH COOLING WATER APPLICATION)

C6.7.1 Condensers shall be of the manually cleanable type capable of being retubed ‘in-situ’.

C6.7.2 For fresh water condenser cooling applications, the condenser shall be of steel and the water boxes/end covers shall be of steel or cast iron.

C6.7.3 The tubes shall be of copper, aluminium brass, cupro-nickel, grade 316 stainless steel or as otherwise indicated in the Particular Specification. The tube plates may be of the same alloys or alternatively made in mild steel with a ‘Cladding’ of stainless steel.
C6.7.4 Internal baffles and other fittings in either water or refrigerant circuits shall be made of material such that they will not corrode or set up corrosion or permit electro-chemical action with the liquids and/or other materials used in the condensers.

C6.7.5 End water boxes shall be designed to provide adequate space for water movement such that there is no erosion of the tube ends. In general, this requires the water box end to be domed rather than flat. The water boxes shall be epoxy resin coated internally to prevent corrosion.

C6.7.6 End box covers shall be removable, and allow easy access for cleaning the tubes. Means shall be provided for venting and draining of the water side of the unit.

C6.7.7 The design fouling factor on the water side of the tubes shall be 0.000044 m$^2$ °C/W for cooling tower fresh water.

C6.8 CONDENSERS, SHELL & TUBE (SEA OR BRACKISH COOLING WATER APPLICATION)

C6.8.1 Condensers shall be of the manually cleanable type capable of being re-tubed ‘in-situ’.

C6.8.2 For sea water or brackish water condenser cooling applications, the condenser shell shall be of steel and the water box/end covers shall be of steel or cast iron.

C6.8.3 The tubes shall be titanium and the tube plate titanium clad steel.

C6.8.4 Ditto as Sub-section C6.7.4.

C6.8.5 Ditto as Sub-section C6.7.5 In addition the water boxes shall be provided internally with a sacrificial zinc anode at both ends.

C6.8.6 Ditto as Sub-section C6.7.6.

C6.8.7 Ditto as Sub-section C6.7.7 except that the design fouling factor shall be 0.000132 m$^2$ °C/W

C6.9 CONDENSERS, SHELL AND TUBE-GENERAL REQUIREMENT

C6.9.1 The positioning of the condenser shall be such that removal or maintenance of the tubes is not obstructed by walls, pipework, valves etc.

C6.9.2 Means shall be provided for the controlled venting of non-condensables from the refrigerant side of the condenser. For Refrigerant134a this may be manually controlled.

C6.9.3 Automatic control of the condensing pressure shall be incorporated.
C6.9.4 The refrigerant and water systems shall be pressure tested at the manufacturer’s work in accordance with Section A9 and ISO 1662.

**C6.10 CONDENSERS, AIR COOLED**

C6.10.1 Air cooled condensers shall have copper tubes with:

- Aluminium fin coated with corrosion protection coating, or
- Electro-tinned copper fins, or
- As otherwise indicated in the Particular Specification.

Corrosion protection coating of the condenser fins shall be applied in factory by the chiller manufacturer. Fins with minor damage shall be combed straight. Units with extensive damage to fins will not be accepted. Provision shall be made for the purging of non-condensables from the condenser.

C6.10.2 Air cooled condensers mounted outside buildings shall have weather-proof fan motors. The units shall discharge air vertically upwards.

C6.10.3 Automatic control of the condensing pressure shall be incorporated. Where modulation of air flow is by outlet dampers only, the fan motor shall be selected for this application and arranged so that it is de-energised on complete closure of the dampers.

C6.10.4 Fans shall comply with limitations on permitted noise levels where indicated in the Particular Specification. Fans shall have sufficient static pressure to cater for the additional acoustic treatment such as silencer, if any, in order to meet the noise requirements set out in Section C8 and the Particular Specification.

C6.10.5 The complete condenser coil shall be pressure tested at the manufacturer’s work in accordance with Section A9.

**C6.11 CONDENSERS, EVAPORATIVE**

These are not normally used in Hong Kong. Should such equipment be required, it will be fully detailed with in the Particular Specification.

**C6.12 COOLING TOWER**

C6.12.1 Cooling towers shall be of the type with induced or forced draught fans as indicated. The entering and leaving water temperatures and the water flow rate shall be suitable for peak heat rejection rate at the maximum ambient wet bulb temperature indicated in the Particular Specification.

C6.12.2 Casings shall be of glass reinforced plastics (GRP), or as indicated. The casing shall have a treatment to minimise corrosion or decay and suitable for the casing material used. The casing and structure shall withstand extreme typhoon gale force winds from any direction.
C6.12.3 The water distribution system shall be easily cleanable to minimise collection of deposits and growth of algae which might encourage the growth of “legionella pneumophila” bacteria, and also be protected by a strainer. Open distribution pans or troughs shall be fitted with coarse mesh grids to exclude debris.

C6.12.4 Fill shall be of the film-type, vacu-formed PVC, with louvres and drift eliminators formed as part of the fill sheets. Fill sheets shall be individually suspended from stainless steel structural tubing, or by other suitable methods, supported by the tower columns and intermediate stainless steel panels, and shall be elevated above the floor of the cold water basin to facilitate cleaning. Air inlet faces of the tower shall be free of water splash-out, and guaranteed drift losses shall not exceed 0.005% of the design water flow. All packing shall be resistant to corrosive attack by algae, fungal growth, the type of condenser water used or the chemicals used to treat the condenser water.

C6.12.5 Where the tower is to circulate sea water, treated wastewater effluents or brackish well water, all components must be capable of withstanding the corrosive effects of these liquids. All metal parts shall be of zinc free bronze or suitable grades of stainless steel coated after installation by heavy bituminous or suitable epoxy resin coatings. Measures shall also be taken against insect and fungus attack. The packing material shall not distort in any manner which would obstruct the air or water flow.

C6.12.6 The cooling tower ‘basin’ shall be provided in reinforced concrete to a specified standard by the Building Contractor. Alternatively, if specified to be provided in the Specialist Services Contract, it shall be of suitable stainless steel, GRP or as otherwise indicated. Sheet mild steel basins if specified (for fresh water applications only) shall be hot dipped galvanised after manufacture and have two coats of an approved anti-corrosion paint applied.

C6.12.7 The GRP hot water distribution basin shall be equipped with metering orifice-type nozzles to deliver incoming water by gravity to the fill. Nozzles shall be easily removable and replaceable.

C6.12.8 The GRP cold water basin shall be sealed watertight, and shall include a float-operated mechanical make-up valve, a 100 mm diameter overflow connection and a depressed GRP sump complete with a debris screen made of stainless steel or other suitable corrosion resistant material. The assembly shall be hot-dip galvanized after fabrication and painted.

C6.12.9 The capacity of the basin shall be sufficient to prevent overflow when the tower is at rest. There shall be adequate and easy access for cleaning out the basin.

C6.12.10 Fans shall be of the axial type mounted to provide a vertical upwards air discharge. In circumstances where centrifugal units are required, these will be fully specified in the Particular Specification.
Particular attention must be given to the limitations on permitted noise levels, where indicated. However, where not indicated, noise levels must be restricted and must be stated with the plant offered. Plant likely to generate unacceptable noise will not be accepted.

Fan casings and impellers shall either be made of corrosion resistant material or proofed against corrosion after manufacture. Fan motors shall be totally enclosed and weatherproofed. Fan motors on induced draught units shall have suitable protective treatment as they will be mounted in the moist air stream.

Belt or gear drives shall be readily accessible but fully protected against the weather and personnel. Anti-vibration ‘cut-out’ devices shall be provided to protect the fans drive etc. Warning of a ‘cut-out’ shall be wired back to the plantroom in order to draw attention to any such problem.

C6.12.11 A bleed pipe with stop valve and flow regulating device shall be provided on each cooling tower.

C6.12.12 Where indicated, chemical treatment equipment for maintenance of cooling water quality shall be provided generally in accordance with Section A7.

C6.13 EVAPORATORS, SHELL & TUBE WATER CHILLING

C6.13.1 Evaporators shall be of the shell and tube type, capable of being re-tubed ‘in-situ’. Where an evaporator which cannot be re-tubed ‘in-situ’ is required, it shall have the refrigerant and water connections flanged and be mounted on the packaged unit in a manner which permits easy removal. The design fouling factor on the closed circulation water side of the tubes shall be 0.000018 m²°C/W.

C6.13.2 The evaporator shell and tube plates shall be of steel and the water boxes/end covers shall be of steel or cast iron. The tubes shall be of copper, aluminium brass, cupro-nickel, grade 316 stainless steel or as otherwise indicated in the Particular Specification. The water box/end covers shall be removable and the plant components arranged such that the space for tube removal is not obstructed.

C6.13.3 The flow of refrigerant to a multiple circuit dry expansion evaporator shall be controlled by an externally equalised thermostatic or electronic expansion valve which shall not ‘hunt’ at any step of compressor unloading. The design of the refrigerant passages in direct expansion type evaporators shall be such that any oil present is always carried back to the compressor at the lowest stage of capacity reduction.

C6.13.4 Where a fixed orifice expansion system is used with a semi-flooded evaporator, a durable nameplate shall be permanently fixed adjacent to the sight glass, in the refrigerant liquid pipe feeding the orifice, with wording as follows:-
‘Bubbles do not always indicate refrigerant undercharge. The Contractor shall refer to special charging instructions’ by the Manufacturer for refrigerant changing.

C6.13.5 Provision shall be made on flooded and semi-flooded evaporators for returning oil from the evaporator to the compressor. If the system uses and passes oil-rich refrigerant into the compressor suction pipe it shall not damage the compressor or cause foaming of the oil in the sump.

C6.13.6 The refrigerant and water systems shall be pressure tested at the manufacturer’s works in accordance with Section A9 and ISO1662.

C6.14 EVAPORATORS, AIR COOLING

C6.14.1 Air coolers using direct expansion of primary refrigerant shall be provided with refrigerant distributors. Connections to the tubes shall be designed to ensure equal flow of refrigerant to each tube.

C6.14.2 The flow of refrigerant to a multiple circuit with dry expansion evaporator shall be controlled by an externally equalised thermostatic or electronic expansion valve which shall not ‘hunt’ at any step of compressor unloading.

C6.14.3 The design of the refrigerant passages in direct expansion type evaporation shall ensure that the return (or suction) connections are arranged such that any oil present is always carried back to the compressor even at the lowest stage of capacity reduction.

C6.15 PLATE TYPE HEAT EXCHANGER

C6.15.1 Heat exchangers shall consist of most energy efficient metal plates pressed into a “Herring Bone” pattern and securely clamped between nitrile rubber gaskets by the pressure end plates of the mild steel framework. Plates shall be stainless steel for fresh water or titanium for sea/well water. The plates shall be suspended from the top bar of the framework and located on the bottom guide bar. No part of the mild steel framework shall be in contact with the heat transfer fluids.

C6.15.2 Heat transfer plates shall be clamped by lateral bolts between a stationary frame plate and a movable pressure plate such that opening of the plate heat exchangers can be done without removing any connecting pipes.

C6.15.3 Heat exchanger shall be designed to give a high heat transfer efficiency to achieve close approach temperatures as low as 1 °C.

C6.15.4 Heat exchanger frame shall be of mild steel and shall be suitable for bolting to a horizontal deck. The frames shall be arranged such that when the tie bars are loosened, full access to all plate surfaces is provided for cleaning and maintenance. The entire framework and all parts of the units shall be factory treated to prevent corrosion such that the heat exchanger shall be capable of corrosive environment. All
holding down bolts shall be of high tensile carbon steel with plastic tube protection. Each shall be equipped with bearing boxes and a locking washer enables the bolts to be opened from the fixed cover. No welded parts are allowed.

C6.15.5 Inlet and outlet ports shall be rubber lined or metal lined constructed on the fixed frame plate only.

C6.15.6 The heat transfer plates for fresh water application shall be of stainless steel and in a corrugated pattern with thickness of 0.6 mm minimum, and pressing depth of about 3.20 mm with pressure rating a minimum of 1000 kPa or other rating to suit system design as specified. Maximum plate pack length shall not exceed 45% of the total framework length. Double gaskets shall be provided around the bypass port on each plate, with a drain hole between the gaskets to facilitate leak detection.

C6.15.7 Distribution area shall be ‘chocolate pattern’ and the flow pattern shall be ‘counterflow’. Gasket shall be on every plate to eliminate inter leakage between media.

C6.15.8 The heat exchanger units shall be pressure tested in the factory prior to delivery. The plate heat exchanger shall have a working pressure range of 1000 to 2500 kPa and shall be tested with a minimum pressure of 1500 to 3500 kPa for 24 hours suitable to the system design application as specified. Full certification of test results and guarantee for 5-year performance free from leakage by the manufacturer shall be provided.

C6.15.9 The heat exchanger for chilled or hot water application shall be properly insulated with optimum efficiency and robust insulation against heat loss. The insulation panels shall be of the double skin aluminium/stainless steel cladded type with handles suitable for easy removable for plates access for inspection and maintenance. An insulated stainless steel drip tray shall also be equipped for chilled water application.

C6.16 LIQUID RECEIVERS

C6.16.1 Except in the case of window units, factory package units and hermetic sealed units equipped with oversized condenser to hold the system refrigerant during pump down operation, all other refrigeration equipment/system with capacity over 350 kW are to be equipped with a refrigerant liquid receiver of sufficient capacity to take the whole charge of the system. The liquid receiver shall consist of a steel shell with dished endplates. It shall be complete with inlet and outlet valves, relief valves, sight glasses and all necessary fittings and accessories.

C6.16.2 Liquid refrigerant receivers shall be separate units. Combination condenser/receivers are not acceptable. One receiver shall be provided for each condensing unit.

C6.16.3 The liquid receiver shall have a capacity of 1.2 times the system charge and wherever possible, shall be provided as part of the packaged chiller
unit completely tubed up and factory tested. A factory test certificate for pressure vessel safety operation shall be provided.

C6.17 PRESSURE TESTING

C6.17.1 The units previously mentioned shall have a strength and leakage pressure test after manufacture. The pressure applied on the refrigerant side shall be as indicated in the table in Section A9.

C6.17.2 A pressure test equal to the low side test pressure quoted in Sub-section C6.17.1 mentioned above for the refrigerant being used, shall be applied to the refrigerant system after all piping has been fitted. This test shall be in addition to the pressure test on each unit at completion of manufacture.

C6.17.3 Pressure tests for condenser water circuits from and to cooling towers or other sources shall be in accordance with Section A9 of this General Specification.

C6.18 PUMP DOWN OF SYSTEM

C6.18.1 The control system for compressors in direct expansion systems shall be so arranged that, on the compressor stop circuit being actuated, the compressor will automatically pump down the system before it stops running. The following features shall therefore be incorporated:

(a) A discharge line check valve.

(b) The low pressure cut-out shall be set at the pressure corresponding to the following temperatures for air conditioning applications:

<table>
<thead>
<tr>
<th>Refrigerant</th>
<th>Cut out</th>
<th>Cut in</th>
</tr>
</thead>
<tbody>
<tr>
<td>R134a</td>
<td>-15°C</td>
<td>-3.9°C</td>
</tr>
<tr>
<td>R407c</td>
<td>-2°C</td>
<td>0.2°C</td>
</tr>
<tr>
<td>Ammonia</td>
<td>-2.2°C</td>
<td>0.2°C</td>
</tr>
</tbody>
</table>

C6.18.2 Pump down will not be required:

(a) Where the compressor is stopped by a safety cut-out when its driving power will be immediately terminated.

(b) On fully manually operated systems.
C6.19 REFRIGERANT PIPEWORK

C6.19.1 Pipework for refrigerant systems shall be of copper or steel, which shall be internally degreased and cleaned. Copper pipe shall be of refrigeration quality (i.e. material to BS EN 1057).

C6.19.2 For all chloro-fluoro-methane or ethane compounds:

(a) All pipes up to 18 mm OD shall be of fully annealed copper.

(b) All pipes from 22 mm to 108 mm OD shall be of hard drawn copper.

(c) All pipes over 108 mm OD shall be of black extra heavy seamless steel pipe to ISO 2604 grade 360.

(d) On fully packaged chiller units, pipework other than copper, i.e. steel fitted and tested in the factory as standard production for the units, will be acceptable subject to notification and written approval by the Architect.

C6.19.3 For ammonia system:

Steel - whatever size is technically necessary or as specified in the Particular Specification.

All materials used in the refrigerant circuit shall be suitable for use in the presence of ammonia refrigerant or lubricating oil, or a combination of both, and comply with ANSI Code B31.5, 1974 or ASME Boiler and Pressure Vessel Code, 1984 Section VIII, and meet with system pressure-temperature requirement so that they will not corrode or cause corrosion when in contact with the fluids conveyed.

C6.19.4 Size of Refrigerant Piping:

Refrigerant piping shall be sized to avoid excessive pressure drop of the fluids or gases they carry. The recommendations of the Chartered Institution of Building Services Engineers (UK) and/or the American Society of Heating, Refrigeration and Air-conditioning Engineers/or other reputable/factory standards approved by the Architect on the sizing of refrigerant piping shall be complied with.

C6.20 REFRIGERATION PLANT ACCESSORIES & CONTROLS

C6.20.1 Every refrigeration system shall be protected by a pressure relief device unless it is so constructed that pressure due to fire conditions would be safely relieved. The equipment provided shall comply with ISO 1662 and the outlet piped to discharge outside the building.

C6.20.2 Systems using a thermostatic expansion valve shall have the following items preceding it in the refrigerant liquid pipe:
- A solenoid valve
- A sight glass
- A refrigerant drier (replaceable)
- A refrigerant strainer
- A capped refrigerant charging valve

C6.20.3 An evaporator pressure regulating valve where fitted shall be protected by a strainer, and an evaporator pressure gauge shall be provided, upstream of the valve, fitted with means of isolation.

C6.20.4 Units having a direct expansion evaporator at a higher level than the compressor shall operate on a pump down cycle. On water chilling installations, the chilled water pump shall be kept running during this process.

C6.20.5 Refrigerant stop valves which incorporate a spindle gland shall be of the back seat type. The spindle gland shall be serviceable with the valve ‘in-situ’.

C6.20.6 A flow switch shall be provided in the chilled water pipeline to each shell and tube evaporator to prevent the compressor starting or continuing to run if the water flow is below the minimum stipulated by the evaporator manufacturer.

C6.20.7 A low temperature thermostat with hand reset shall be provided for each shell and tube evaporator to stop the compressor(s) if the chilled water flow temperature falls below +3 °C.

C6.20.8 Full flow driers with strainers shall be supplied for all refrigerant liquid lines and shall be complete with isolating valves and bypass arrangements. Driers shall be of the renewable cartridge type.

A suitable colour moisture indicator shall be provided, either built-in to the drier, or as a separate component installed adjacent to the drier to show through a suitable glass eye whether the moisture content of the refrigerant is within permissible limits.

C6.20.9 Strainers shall be provided before all expansion valves, float valves, solenoid valves, etc. Except where the expansion valve is fitted just downstream of a solenoid valve, only one strainer needs to be fitted.

C6.20.10 Full flow strainers of the cleanable and renewable type shall be fitted at the suction of all compressors.

All strainers and driers shall be easily and readily accessible for cleaning or replacement of cartridges.

C6.20.11 Full flow oil filters shall be incorporated in all force-feed lubricating system. Magnetic separators shall also be provided.

C6.20.12 Where oil separation equipment is to be provided, it shall be complete with traps, strainers, floats, receivers and gauges.
The oil separator shall be a fabricated steel shell with dished steel endplates and ample and accessible cleaning handholes. The oil return control floats shall not be fitted inside the shell. No pipes shall be fitted inside the shell. No pipes shall be connected through the lids of cleaning or access holes. Adequate provision shall be made for purifying and flushing the system.

C6.20.13 Energy meters shall be provided for chilled (or hot) water system for energy audit purposes. The specification/requirement of the energy meters shall be as described in Section C10.

C6.21 **ROOF MOUNTED PACKAGED WATER CHILLER PLANTS**

C6.21.1 The Units shall include the number and type of compressors indicated in the Particular Specification, with air cooled condenser coils, condenser fans and motors, shell and tube direct expansion evaporator water chiller.

C6.21.2 Expansion valves controls and safety devices shall all be housed in a substantial weatherproofed casing.

C6.21.3 Where specified in the Particular Specification, units shall have full noise suppression treatment with outlet silencers generally as covered in Sections B8 and C8.

C6.21.4 Unitary package chiller units shall conform to and shall have rated and tested capacity to the requirements of ARI Standard 210 or other equal Internationally Recognised Standard accepted by the Architect.

C6.22 **HEAT RECOVERY CHILLER**

C6.22.1 Heat recovery chiller unit shall be complete with a heat recovery condenser and condensing unit, three-way valve, receivers etc. The exact configuration of these devices shall follow the details recommended by the chiller manufacturer. The heat which is normally rejected to the air-cooled or water-cooled condenser shall be reclaimed and made available through the heat recovery condenser and other provisions as specified, for a variety of uses aiming to optimize the building energy performance.

C6.22.2 All the waste heat shall be reclaimed by adding a heat recovery condenser, refrigerant control valve, liquid line receiver and controls to the standard air-cooled or water-cooled chiller, making it as a heat recovery chiller. The heat recovery chiller shall have only one refrigerant control valve which makes its operation reliable, simple to control and easy to maintain.

C6.22.3 During operation in the cooling mode, the hot refrigerant gas shall be condensed only in the normal air-cooled or water-cooled condenser, the system cooling load heat and the heat of compression shall be rejected to the atmosphere via this condenser. The system shall sub-cool the liquid refrigerant which shall increase the capacity of the machine by up to 12 percent without increasing power consumption. The condenser fans shall
operate in a cycle according to the outside temperature. Suitable air dampers/head pressure control devices shall be equipped to maximise the machine heating or cooling output efficiency.

C6.22.4 Under heat recovery mode, the refrigerant gas shall condense in the shell-and-tube heat recovery condenser. The high pressure and temperature refrigerant gas shall flow into the heat recovery condenser and the heat released from the cooling load and heat of compression shall be rejected to the heating water circuit.

C6.22.5 The three-way modulation valve shall control refrigerant flow through the heat recovery and normal air-cooled or water-cooled condensers. It shall be controlled by the system heating requirements. The unit shall operate with 0 to 100 percent heat recovery, so that part of the heat shall be rejected and part recovered for system water heating or room relative humidity (RH) control application.

C6.22.6 The heat reclaim condenser shell shall be of carbon steel. Multiple circuit dry expansion water boxes at a minimum of 1050 kPa or to suit system design shall be provided which shall have steel pipe stub connections grooved for couplings.

C6.22.7 The heat exchanger tubes shall be of seamless copper tubing rolled into tube header sheets. Other energy efficient heat exchange equipment/devices may be accepted subject to the approval of the Architect.

C6.23 HEAT PUMP

C6.23.1 Heat pump shall be of the air-to-water or water-to-water type as specified in the Particular Specification.

C6.23.2 Air-to-water or water-to-water heat pump shall be operating in reverse cycle of a normal chiller. Each heat pump shall include compressor, compressor motor, evaporator, condenser, lubrication system, capacity control, solid state control centre and indication accessories. Relevant content of Section C6 concerning various components of a normal packaged chiller shall also be applied where applicable.

C6.23.3 The refrigerant circuit shall be leak tested at factory, evacuated and pumped up with a holding charge of refrigerant under positive pressure prior to the delivery of the unit. If this holding charge is lost on arrival, the system will not be accepted.

C6.23.4 The unit shall consist of factory assembled, charged, wired, insulated and tested system using an environmental friendly refrigerant.

C6.23.5 The capacity control of the heat pump shall be based on the leaving hot water temperature sensing in order to maintain constant leaving water temperature.
C6.23.6 A water flow switch shall be installed in the water piping line to prevent the unit from starting when water is not circulation through the evaporator.

**C6.24 ENERGY EFFICIENCY PERFORMANCE**

The refrigeration plant shall be accepted with a minimum coefficient of performance as specified in the following Tables. The values of minimum coefficient of performance are based on the following standard rating conditions:

- Chilled water entering temperature: 12 °C
- Chilled water leaving temperature: 7 °C
- Condenser ambient air temperature: 35 °C
- Condenser water entering temperature: 29 °C (for water-cooled chiller)
- Condenser water leaving temperature: 34 °C (for water-cooled chiller)

Table C6.24 - (1) Minimum coefficient of performance for air-cooled chiller at peak load condition

<table>
<thead>
<tr>
<th>Type of Compressor</th>
<th>Capacity (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Below 400</td>
</tr>
<tr>
<td>Reciprocating</td>
<td>2.4</td>
</tr>
<tr>
<td>Centrifugal</td>
<td>2.7</td>
</tr>
<tr>
<td>Screw or scroll</td>
<td>2.7</td>
</tr>
</tbody>
</table>

Table C6.24 - (2) Minimum coefficient of performance for water-cooled chiller at peak load condition

<table>
<thead>
<tr>
<th>Type of Compressor</th>
<th>Capacity (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Below 500</td>
</tr>
<tr>
<td>Reciprocating</td>
<td>3.2</td>
</tr>
<tr>
<td>Centrifugal</td>
<td>3.8</td>
</tr>
<tr>
<td>Screw or scroll</td>
<td>4.5</td>
</tr>
</tbody>
</table>

For heat pump and heat recovery equipment/applications, the equipment/system coefficient of performance shall not be lower than the requirements as stipulated in the Tables above.

Details of energy efficiency assessments shall be submitted before the equipment is accepted. Factory test and field test reports shall be provided to substantiate the equipment design and performance.

Ample time approved by the Architect shall be allowed for the submission in order to meet with the installation programme.
SECTION C7
ELECTRIC MOTORS AND ELECTRICAL EQUIPMENT

C7.1 LOW VOLTAGE - GENERAL

The mains for the low voltage electrical motors and equipment shall be suitable for a supply as specified in Sub-section A3.1.11.

Unless otherwise indicated, all electrical equipment shall be tropicalised and suitable for use in service conditions as specified in Sub-section A3.1.10. Equipment shall be protected against atmospheric corrosion, including that caused by salt-laden air. Materials used shall not be susceptible to mould growth or attack by vermin.

Cables for power circuits shall not be less than 2.5 mm$^2$ copper conductors and cables for control circuit shall not be less than 1.5 mm$^2$ copper conductors.

The content related with Control and Metering shall be closely read in conjunction with the relevant parts of Sections C4, C5 and C10.

C7.2 LOW VOLTAGE - WIRING FOR REFRIGERATED SITUATIONS

All electric wiring to be installed into refrigerated situations where the temperature is to be maintained at or below 0°C shall be either MICS or elastomeric cables that are applicable for the designed operating environment.

C7.3 LOW VOLTAGE - ELECTRIC MOTORS

C7.3.1 General

All electric motors shall be of the high efficiency squirrel-cage induction type and comply with the relevant parts of IEC 60034.

The motors shall be insulated IEC 60085 with Class F as the minimum insulation.

Motor enclosures shall be in accordance with BS EN 60034-5 and the 'degree of protection' shall be appropriate to the location in which the motors are operating and the environment indicated. Unless otherwise specified, motors shall be protected with enclosures to at least IP 44 for indoor and IP 55 for outdoor application.

Motors of 2.2 kW output or above shall be suitable for operation from three-phase supply.

The synchronous speed of the motor shall not exceed 25 rev/s unless otherwise approved.

C7.3.2 Insulation Test
All low voltage motors shall have a minimum insulation resistance of 1 megaohm between phases and to earth when tested with an approved 500 volt insulation tester.

**C7.3.3 Starting Torque and Current**

Motors shall have starting torque characteristics to suit the connected load and the type of starting, in particular where reciprocating compressors will be used and not fitted with starting unloaders.

Starting current conditions shall conform to the requirements as stipulated in the latest edition of the Supply Rules of the power utility companies.

**C7.3.4 Maintenance Access and Safety**

The electrical and mechanical arrangements of all motors shall be such that the necessary periodical testing, cleaning and maintenance can be carried out in a minimum of time with economy of labour.

**C7.3.5 Noise and Vibration**

All motor rotors shall be dynamically balanced. The vibration and noise level generated by the motors shall not exceed the recommended limits as stipulated in IEC 60034-9 and IEC 60034-14 respectively. The Architect will reject motors that operate with unacceptable noise and vibration.

**C7.3.6 Minimum Motor Efficiency**

Unless otherwise specified, all motors shall have the minimum efficiency in compliance with the Code of Practice for Energy Efficiency of Electrical Installations as listed in Section A6 of this General Specification.

**Table C7.3.6 Motor efficiency**

<table>
<thead>
<tr>
<th>Output Power (kW)</th>
<th>Minimum Efficiency (%)</th>
<th>Output Power (kW)</th>
<th>Minimum Efficiency (%)</th>
<th>Output Power (kW)</th>
<th>Minimum Efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.18</td>
<td>74.9</td>
<td>3.0</td>
<td>88.5</td>
<td>30</td>
<td>94.3</td>
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<tr>
<td>0.25</td>
<td>77.0</td>
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<td>89.4</td>
<td>37</td>
<td>94.7</td>
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<td>0.37</td>
<td>79.2</td>
<td>5.5</td>
<td>90.4</td>
<td>45</td>
<td>95.0</td>
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<tr>
<td>0.55</td>
<td>81.3</td>
<td>7.5</td>
<td>91.3</td>
<td>55</td>
<td>95.3</td>
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<td>82.8</td>
<td>11.0</td>
<td>92.2</td>
<td>75</td>
<td>95.8</td>
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<tr>
<td>1.10</td>
<td>84.6</td>
<td>15.0</td>
<td>93.0</td>
<td>90</td>
<td>96.0</td>
</tr>
<tr>
<td>1.50</td>
<td>85.9</td>
<td>18.5</td>
<td>93.4</td>
<td>110</td>
<td>96.3</td>
</tr>
<tr>
<td>2.20</td>
<td>87.4</td>
<td>22.0</td>
<td>93.8</td>
<td>132</td>
<td>96.5</td>
</tr>
</tbody>
</table>
C7.3.7 Continuous Rating

The motors shall be continuously rated to BS EN 60034-1. They shall be adequately rated to meet the service demands of driven units connected thereto under normal conditions without overload. The continuous rating of the motors shall cover the full specified range of duty plus a further 5% margin for compressors, 15% margin for fans and 10% for pumps.

C7.3.8 Tachometers

In all cases of direct drive (except hermetic), an application point shall be provided for speed checking by a tachometer.

C7.3.9 Terminals

One large terminal box of approved design shall be provided, mounted on the stator casing only. Each end of each stator phase must be brought out to a terminal in the box. For motors rated 10 kW and above, adequate clearance between termination shall be allowed for the use of cable sockets.

C7.3.10 Anti-condensation Heater

Anti-condensation heater shall be provided in sea water pump motors located inside water-front pump chambers, or motors above 30 kW.

C7.3.11 Belt Drives and Pulleys

Belt drives shall comply with BS 3790 and be capable of transmitting at least the rated power output of the driving motor with one belt removed. A minimum of two belts per drive shall be used and all multi-belt drives shall use matched sets.

Slide rails shall be provided for all motors driving through belts. Purpose-made adjusting devices shall be provided to enable belt tension to be altered and motors to be secured.

Belt driven fans shall be fitted with pulleys suitable for the belt drive used. Pulleys may use split taper bushings for drives up to 30 kW. Alternatively, and in any case for output above 30 kW, pulleys shall be secured to the fan and motor shafts by keys fitted into machined keyways. Keys shall be easily accessible so that they can be withdrawn or tightened. Where gib head keys are used they shall not protrude beyond the end of the shaft. For keys without gib heads, they shall be drilled and tapped to accept an extractor bolt.

C7.3.12 Protective Guards

Protective fixed guards shall be provided at all open intakes and exhausts from fans, for all forms of open power transmission systems including belt drives and drive couplings, and to dangerous parts of machinery to
prevent inadequate access or contact. The guards shall comply with the safety requirements stipulated by the Labour Department.

For belt drives, the guards shall be of galvanized steel wire of not less than 2.5 mm diameter attached to a rigid galvanized steel rod or angle framework. The mesh size and the location of the guard shall prevent finger contact with any enclosed danger point. Alternatively guards may be constructed from galvanized sheet steel of not less than 0.8 mm thick stiffened to ensure a rigid enclosure. Removable access panels shall be provided in guards to allow tachometer readings to be taken on both driving and driven shafts and also belt tension to be tested. The sizes of guards including the dimensions and locations of access panels shall also allow the size and position of the motor.

C7.4 LOW VOLTAGE - VARIABLE SPEED DRIVES

C7.4.1 When a variable speed drive (hereinafter referred to as VSD) is specified for a fan or a pump with throughput power up to 150 kVA, it shall be a solid-state converter to convert three phase mains supply as specified in Sub-section A3.1.11 to an adjustable voltage and frequency output at its rated throughput power. VSD shall conform to BS EN 50081 and BS EN 50082 or other similar recognised international standards on Electromagnetic Compatibility (EMC) compliance for industrial or commercial applications and shall be manufactured to ISO 9001. Certificate of compliance shall be issued for each standard rating of VSD used in the Contract after being fully tested at the manufacturing facility.

C7.4.2 The VSD shall be manufactured by a reputable manufacturer which has continuously manufactured VSDs for at least 5 years and their manufacturing facility shall have a local agent to provide full technical support with adequate spares holding and technical expertise in testing, commissioning and trouble-shooting. Training shall be provided by the manufacturer's representatives for government staff on operational and maintenance aspects including essential trouble-shooting techniques.

C7.4.3 The VSD shall incorporate a 6-pulse (as a minimum) full-wave uncontrolled diode bridge, fixed voltage fed DC link with inductors and capacitors to form a filter, a mains filter for EMC compliance, a pulse width modulation (PWM) inverter bridge utilising insulated gate bipolar transistors (IGBTS) and output inductors in the motor lines. The inverter bridge shall be controlled by a microprocessor to produce a pulse width modulation (PWM) waveform or similar technique which would result in full motor voltage and sinusoidal current mains supply in the motor circuit. The VSD shall be equipped with built-in RS 485/232 serial communication ports.

C7.4.4 The VSD shall be capable of continuously delivering rated output voltage even when the mains supply voltage is down to 6% of its nominal value and shall be able to control a standard IEC 60034 3-phase squirrel cage induction motor over a speed range of 20% to 100% continuously and smoothly without the need to de-rate the motor kW rating and to provide total power factor of not less than 0.9 lagging.
without external chokes or power factor correction capacitors, at all loads within the speed range. The inrush current shall be zero and during starting, the current shall start from zero and rise as the load accelerates with no danger of exceeding full load current.

C7.4.5 The VSD shall allow unlimited switching of the motor circuit, at any load and within the controlled speed range without damage and without the need of auxiliary control switching. The VSD shall be capable of automatically reconnecting to a spinning fan and running without tripping, following mains interruption and on transfer from backup source. The VSD shall be capable of running with no motor connected during functional testing. The VSD shall have voltage/frequency (V/f) ratio suitable for centrifugal pumps and fans control. Selectable V/f ratios shall be provided and it shall not be possible to set a constant V/f ratio, to prevent damage to connected equipment and to optimise energy usage.

C7.4.6 The complete VSD unit shall be housed in a single front-access enclosure designed and built as an integral part of the VSD by the VSD manufacturer. The VSD shall be protected to at least IP 44 for indoor and IP 55 for outdoor application, without having to use a secondary enclosure. It shall be suitable for continuous operation without de-rating under ambient temperature of up to 40°C and relative humidity of up to 99% unless otherwise specified. The manufacturer shall arrange for their equipment to be fully tested including motor loading at their manufacturing facility or by an approved testing authority to certify that their equipment conforms to the aforesaid standard. Certificate of compliance shall be issued for each standard rating of VSD used in the Contract after being fully tested at the manufacturing facility or by the testing authority.

C7.4.7 The VSD shall be fully rated to provide the performance as follows: -

(a) Minimum efficiency of 95% at 100% load and not less than 90% at any other operating loads;

(b) Output torque shall be limited to 105% of full load torque;

(c) No facility for reversing the motor rotation shall be incorporated;

(d) The VSD shall have a maximum capacity of 150 kVA as recommended by the Engineering Recommendation G5/3 titled "Limits for Harmonics in the United Kingdom Electricity Supply System" published by the Electricity Council;

(e) The maximum allowable fifth harmonic current distortion expressed in percent of the fundamental input current at the VSD input terminals during operation within the variable speed range shall preferably be less than 35%;

(f) The electromagnetic compatibility shall be comply with BS EN 50081 and BS EN 50082 or equivalent standards.
C7.4.8 The following minimum features shall be incorporated in the VSD unit complete with an integral control panel:

(a) Acceptance of digital and analogue 0-10 V, 4-20 mA control signals;

(b) Integral measurement and selectable display of:
   - output current
   - output voltage
   - output frequency
   - output speed
   - output power
   - motor temperature

(c) Display of warning/fault/alarm status;

(d) Ability to transmit data on the RS 485/232 output for remote interrogating and reprogramming;

(e) Programmable relay output (250V 2A) and programmable analogue output of 4-20mA or 0-10V DC suitable for the application;

(f) 5 programmable preset speeds (including at least 2 skip frequencies of adjustable bandwidth to overcome mechanical or air system resonance);

(g) Selectable local or remote control;

(h) Provision of the following integral protection against:
   - Loss of mains and motor phase
   - Motor short circuit
   - Motor circuit earth fault
   - Motor overheat
   - Overvoltage
   - VSD overheat
   - Under voltage
   - Input transients
   - VSD and motor overload
   - Mains input accidentally couples to motor output terminals

(i) An integral full 3-term PID control to provide close loop control direct from a signal transmitter without need for external signal conditioning;

(j) A facility for controlling motor anti-condensation heater for heater operation when the motor is idle.
C7.5  LOW VOLTAGE - MOTOR SWITCHGEAR, STARTER AND CONTROL PANELS

C7.5.1 General

Motor switchgear, starters and controls shall be supplied and installed to perform the operation and control of the air-conditioning equipment to be provided. The starters and controls shall be housed in wall-mounted local motor control panels, or floor-standing motor control switchboards as indicated in the Contract Documents. The control panels or switchboards shall incorporate all control devices, timers, accessories and wiring necessary for proper operation.

C7.5.2 Local Motor Control Panels

(a) The local motor control panel shall be of wall-mounted factory built assemblies of low voltage switchboard housing the motor starter and switchgear.

(b) The panel shall be Partially Type-Tested Assemblies (PTTA) as defined in IEC 439-1 and constructed generally to Form 2.

(c) The panel shall be of steel construction, self supporting, with modular top, side and back panels and doors of sheet steel built up on substantial framing with all necessary stiffeners, supports and return edges to provide a rigid construction and clear accessibility to all internal components within the panel. The thickness of the sheet steel shall be at least 1.6 mm.

(d) The panel enclosure shall be of degree of protection of IP 44 for indoor application to IEC 529. All doors shall have hinges and be provided with dust-excluding gasket.

(e) All panels shall, but not be limited to, include the following operational features: -

- Local Auto/On/Off switch for each equipment,
- A starter for each motor,
- Fuse switch or circuit breaker for each equipment,
- Isolating switch for each main incoming supply and for each motor starter,
- Protective, control and auxiliary relays,
- Current transformer,
- Current ammeter for each equipment with phase selection switch for each motor,
- Voltmeter for panel with power supply of 60 A or above,
- Hour run meter,
- Indicating lamps, push buttons, selectors and control switches,
- Emergency stop push buttons,
- Labelling.
Unless otherwise specified, the components above shall comply with the requirements stipulated in the Electrical General Specification.

C7.5.3 Motor Control Switchboard

The motor control switchboard (hereafter called the “Switchboard”) shall be a free-standing floor-mounted low voltage switchboard to group centrally the motor starters, controls and switchgear for the air-conditioning and ventilation equipment etc.

The Switchboard shall, but not be limited to, include the following provisions: -

- Local Auto/On/Off switch for each equipment
- Air circuit breaker, fuse switch and/or moulded case circuit breaker
- Busbars
- Isolating switch for each main incoming supply and for each motor starter
- A starter for each motor
- Protective, control and auxiliary relays
- Current transformer
- Current ammeter for each equipment with phase selection switch for each motor
- Voltmeter for panel with power supply of 60 A or above
- Hour run meter
- Indicating lamps, push buttons, selector and control switches
- Emergency stop push buttons
- Labelling

Unless otherwise specified, the Switchboard and associated components above shall comply with the requirements stipulated in the Electrical General Specification.

C7.5.4 Motor Starters

(a) General Requirements

(i) Motor starters shall generally comply with the requirements of the Electrical General Specification and with the BS EN 60947-4-1 or IEC 292 standard.

(ii) The duty of the starters shall be suitable for the mechanical and electrical duties imposed by the motors being switched and in particular, the starting torque, current, starting time and frequency of operation.

(iii) Motor of more than 0.5 kW rating shall be provided with a starter designed to perform the following functions efficiently and safely: -

- To start the motor without damage to the drive or driven equipment whilst regulating the starting current
to the satisfaction of the power supply company and ensuring that at all stages of starting, the motor will develop sufficient torque to accelerate the load.

- To stop the motor.

- To prevent damage to the motor due to overload, under voltage, disconnection of one phase etc.

- To prevent damage to reduced voltage started motors and danger to personnel due to resumption of the electricity supply following a failure.

- To limit the damage to the motor due to stalling or internal electrical or mechanical faults by quickly disconnecting the supply.

- To prevent damage to the motor or the starter itself due to improper unskilled or hesitant operation or failure to complete a starting sequence once it is connected.

(iv) In general, the following types of motor starters will be accepted subject to conformation to the Supply Rules of the power utility companies:

Table C7.5.4 (a)(iv) Motor starters

<table>
<thead>
<tr>
<th>Motors up to 0.37 kW output</th>
<th>‘ON/OFF’ switch or direct-on-line starter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Over 0.37 kW and up to 7.5 kW</td>
<td>direct-on-line starter</td>
</tr>
<tr>
<td>Over 7.5 kW and up to 55 kW</td>
<td>star-delta starter</td>
</tr>
<tr>
<td>Over 55 kW</td>
<td>auto-transformer starter</td>
</tr>
</tbody>
</table>

Where specified in the Contract Documents, soft-start motor starter can be used to start motors over 2 kW.

(v) Each motor starter assembly shall comprises fused switchgear, contactors, protection relays and associated accessories. For starter to be installed in motor control switchboard, the whole unit shall be enclosed in the switchboard from which no access can be gained to adjoining sections of the switchboard.

(vi) All starters shall be of the electrically held-on pattern and shall not release until the voltage falls below 75% of nominal value.

(vii) All contactors shall be of the electro-magnetic type and shall comply with BS EN 60947-1 or IEC 158, utilisation category AC-3. The duty rating of the contactors shall not
be less than intermittent duty class 0.1 60% on-load factor.

(viii) Control circuits shall be operated on main supply derived from the control panel or switchboard, and protected by fuse to BS 88: Part 2.

(ix) Where duplicate equipment is provided, the starter for each equipment shall be housed in a separate panel. Unless otherwise indicated, where an equipment is provided with duplicate motors, two starters shall be supplied; a single starter with a local changeover switch will not be accepted.

(b) Direct-on-line (DOL) Starters

(i) Motors rated below 7.5kW shall be direct-on-line provided that the maximum starting current does not exceed six times the rated motor full load current, otherwise star-delta starters shall be provided.

(ii) The starters shall, but not be limited to, include the following:

- Fused switchgear.

- Triple pole air break contactor.

- A triple pole motor protection unit incorporating over-current and single-phasing protection with manual reset facilities. The over-current protection unit shall be of the thermal type, with minimum setting of 110% of full load current.

- Under-volt release protection device. Unless otherwise specified, it shall be arranged to provide automatic restart on restoration of mains voltage.

- Current transformers with suitable ratio, output and accuracy for motor protection.

- Local/off/remote control selector switch lockable in each position.

- Start and stop push buttons.

- Indicating lamps for motor running, off and tripped on fault.

- Dry contacts wired to terminals for remote indication of motor running, off, tripped on fault and summary alarm to supervisory control panels.
- Terminals wired to provide for connection to emergency stop push button and remote start/stop of the motor.

- Hour run meter.

- Lamp test button.

- Any other items required to effect satisfactory motor starting and control as specified elsewhere in the Specification.

(c) Star-delta Starters

(i) Motors rated at and above 7.5kW and up to 55kW shall be star-delta started to limit the maximum starting current to within 2.5 times the rated motor full load current.

(ii) Star-delta starters shall be equipped as per DOL starters specified above, with the following additional provisions:

- Triple pole air break contactors with electrical and mechanical interlock arranged for automatic star-delta transition.

- Calibrated and adjustable solid state timer for automatic star-delta transition.

- A triple pole motor protection unit incorporating over-current, single-phasing and earth leakage protection with manual reset facilities. The over-current protection unit shall be of the thermal type, with a minimum setting of 110% of full load current. The earth leakage protection unit shall be selected to isolate the motor circuit with a maximum fault disconnection time of 5 seconds in case of earth leakage without causing nuisance tripping of the motor circuit due to motor starting and transient current transformer saturation.

(d) Auto-transformer Starters

(i) Motors rated above 55kW shall be reduced voltage started by means of auto-transformer to limit the maximum starting current to within 2.5 times the rated motor full load current.

(ii) Reduced voltage starters shall be equipped as per star-delta starters specified above, with the following additional provisions:
- Triple pole air break contactor with electrical and mechanical interlock arranged for automatic reduced voltage transition.

- Air-cooled copper winding auto-transformer with Class F insulation enclosed in an earthed metal casing suitably ventilated by splash proof louvres. Suitable tappings shall be arranged for closed transition reduced voltage motor starting.

- Calibrated and adjustable solid state timers for switching over from reduced voltage to full voltage connection.

(e) **Solid State Softstart Motor Starter**

(i) The solid state soft motor starter (hereinafter referred to as 'softstarter') shall be of the power electronic type motor starting device. It shall control the voltage applied to the motor smoothly by varying the conduction angle of the solid state AC switches which can be triacs, reverse parallel connected SCR-diode circuit or reverse parallel connected SCR-SCR circuit etc., or by using other similar technique.

(ii) The softstarter shall be manufactured to conform to the following relevant standards or other similar recognised international standards:

<table>
<thead>
<tr>
<th>Standards</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BS EN 60068-2 (IEC 68-2-6)</td>
<td>for vibration resistance</td>
</tr>
<tr>
<td>BS EN 60068-2-27 (IEC 68-2-27)</td>
<td>for shock resistance</td>
</tr>
<tr>
<td>BS EN 60801, 60802 (IEC 801)</td>
<td>for radio-electrical interference immunity</td>
</tr>
<tr>
<td>BS EN 50081</td>
<td>for electromagnetic compatibility</td>
</tr>
</tbody>
</table>

(iii) The softstarter shall be manufactured by a reputable manufacturer who has continuously manufactured softstarter for at least 5 years and their manufacturing facility shall have a local agent to provide full technical support, including adequate spares holding and technical expertise in testing, commissioning and trouble-shooting. Training shall be provided by the manufacturer's representatives for government staff on operational and maintenance aspects including essential trouble-shooting techniques.
(iv) Full technical details of the softstarter provided by the manufacturer shall be submitted and shall cover at least the following:

- Technical guide on its applications,
- Schematic and wiring drawings, down to circuit board level where possible,
- Shop drawings and as-fitted drawings,
- Operation manuals with commissioning guide,
- Maintenance manuals with trouble-shooting guide and,
- Parts list and recommended spare parts with price.

(v) Degree of Protection of Enclosure

The softstarter shall be protected to at least IP44 for indoor and IP55 for outdoor application by a single front-access enclosure and shall be suitable for operation without derating under ambient temperature of up to 40 °C and relative humidity of up to 99%.

(vi) Voltage and Power Rating

Unless otherwise specified, the rated operational voltage shall be as specified in Sub-section A3.1.11. The rated power and quantities of the softstarters shall be as indicated in the Particular Specification or the Drawings.

(vii) Mode of Operation

The softstarter shall provide the following modes of operation and shall be transitionless without causing any current inrush and torque surges during operation:

- Voltage ramp - The motor voltage shall begin initially at a preset 'start voltage' and increase to line voltage at a preset 'ramp rate'. The acceleration ramp time shall be adjustable up to 30 sec.

- Current limitation - It shall be capable of limiting the maximum starting current which shall be adjustable up to 5 times of rated current.

- Soft stop - A deceleration voltage ramp shall be applied to the motor for applications which require an extended coast to rest. The voltage ramp down time shall be adjustable up to 60 sec.

- Kickstart - A current pulse shall be provided in the softstarter to develop additional torque when started for loads which may need a boost to get started.
- Energy saving - Energy saving mode shall be provided such that when the motor is lightly loaded or unloaded for long periods of time, it shall automatically decrease motor power losses by controlling the motor terminal voltage.

- Apart from the above, other modes of operation such as voltage pedestal starting, full voltage starting, D.C. injection braking etc. shall also be provided when specified in the Particular Specification.

(viii) Protection

The softstarter shall have integral protection to the motor and softstarter and LED diagnostics to aid in set-up and troubleshooting. The protection shall include:

- Thermal overload protection of the motor and softstarter,
- Mains supply protection for phase failure and phase unbalance,
- Internal fault protection and stalled motor protection.

(ix) Auxiliary Contact

The softstarter shall provide auxiliary contacts for end of starting (by-pass) and fault condition. The output relay contact shall be suitable for 220 V AC operation in category AC11 and DC operation in category DC11.

(x) Selection of Softstarter and Operating Precautions

- The starting current-speed transition curve of the selected softstarter shall closely match with the starting torque-speed characteristics of the motor and loading. The ratings of the softstarter shall base on 'hot start' operation i.e. the motor shall re-start immediately after operating at maximum rating for a period of time.

- The motor associated with the softstarter shall be capable of starting the driven load when supplied at reduced voltage and current. In case of severe duty, check with the motor manufacturer shall be carried out that its derating is compatible with the operating cycle and the starting times.

- The heat sink of the softstarter shall be of good quality aluminium construction and shall provide sufficient thermal inertia to permit successful starting of the motor without exceeding the permitted junction temperature of the solid state AC switches.
- The softstarter shall be capable of continuously delivering rated output voltage (or reduced output voltage under energy saving mode) with power factor of not less than 0.9 lagging without external chokes or power factor correction capacitors at any load. When using a by-pass contactor, the order to close and open the contactor shall be controlled by the built-in signal of the softstarter.

- The softstarter shall have the possibility to accept DC input from external device such as Programmable Logic Controller (PLC) for controlling the start and stop of the unit.

- Semiconductor fuses shall be available as an option and have the characteristics suitable to protect the softstarter.

- The solid state AC switches shall have a blocking voltage of at least 1400 V for 415 V system with a rate of rise of reapplied voltage tolerance of at least 1000 V per microsecond. However, an isolation contactor or isolator shall be available as an option to isolate the supply in the 'Off' state of the softstarter for the safety of the operator.

- UNDER NO CIRCUMSTANCES shall all the power factor correction equipment be connected between the softstarter and the motor. If power factor correction equipment is employed, it shall be connected to the supply side of the softstarter.

**C7.6 LOW VOLTAGE - AUTOMATIC POWER FACTOR CORRECTION CAPACITORS**

Power factor correction capacitor equipment including capacitors, cables, cable glands, control relays, trunking, control wiring, current transformers etc. shall be provided such that the overall power factor at the motor control switchboard is improved to not less than 0.85. The net rating of each capacitor bank shall be calculated and be suitable for operating at 380 V, 3 phase, 50 Hz.

The capacitor bank shall be of the wall or floor mounting cubicle-type, built up from static primary capacitor unit. The capacitor bank together with its associated equipment shall not be installed inside the switchboard, where practicable. However, if it is unavoidable due to physical constraint, the equipment shall be installed in a separate compartment segregated from the rest of the switchboard.

The static primary capacitor unit shall be of the hermetically sealed dry type and manufactured from continuous reel metal foil and high quality tissue. This static primary capacitor unit shall comply with the requirements of IEC 60070. Oil type capacitors will be rejected.
Each capacitor bank shall be fitted with a continuously rated low loss discharge assembly which shall discharge the entire capacitor bank from the peak alternating voltage to a voltage not exceeding 50 volts measured at the capacitor bank terminals one minute after disconnection from the supply.

All exposed ferrous metal surfaces of the capacitor bank where applicable, shall be treated with rust-inhibiting primer paint, undercoat and finished to a colour approved by the Architect.

Automatic multi-step capacitor control relays (reactive type) of suitable VA rating complete with reset device shall be provided to ensure that the amount of power factor improvement in the circuit at any time is commensurate with the load condition and to prevent leading power factor during light load condition.

Current transformers of suitable turns ratio and VA rating and the associated control wiring for the automatic control of capacitor bank shall be provided.

### C7.7 HIGH VOLTAGE - GENERAL

This section covers the design, manufacture, testing and delivery of high voltage induction motors and associated switchgear of rated voltages 3.3 kV, 6.6 kV or 11 kV. The high voltage motors and associated switchgear shall be provided to drive the chiller compressors, water pumps or other loads when high voltage motors are specified in the Contract Documents.

Unless otherwise specified, the following system fault level shall be assumed:

<table>
<thead>
<tr>
<th>Nominal system voltage</th>
<th>3.3 kV</th>
<th>6.6 kV</th>
<th>11 kV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum symmetrical fault level</td>
<td>150 MVA</td>
<td>225 MVA</td>
<td>380 MVA</td>
</tr>
</tbody>
</table>

### C7.8 HIGH VOLTAGE - ELECTRIC MOTORS

#### C7.8.1 Performance Requirements

(a) General Requirements

(i) Type - 3-phase squirrel cage induction motor

(ii) Standards - BS EN 60034-1

(iii) Duty rating - Maximum Continuous Rating (MCR), SI duty.

(iv) Insulation - Class F design for Class B operation, BS EN 60034-1.

(v) Maximum speed - 25 rev/s synchronous speed.

(vi) Vibration level - IEC 60034-14 or BS EN 60034-14 as appropriate.

(vii) Power factor - 0.85 minimum under full load conditions
Electricity Supply

The electricity supply to the high voltage motors shall be 3.3 kV, 6.6 kV or 11 kV 3 phase, as specified in the Contract Documents.

Starting Performance

Unless otherwise specified, the motor shall be provided with auto-transformer starter to limit the starting current to not exceeding 2.5 times of full load current.

The motor shall be designed to permit not less than three starts per hour equally spaced during normal running conditions. The motor shall also be suitable for two starts in succession followed by a 30 minutes interval before attempting another starting sequence.

The minimum voltage at motor windings at starting shall be 50% nominal for motor with auto-transformer starter.

The starting (run-up) torque characteristics of motor at minimum voltage shall be adequate for driving the load to full running speed under the most arduous conditions specified. The accelerating torque at any speed up to the peak torque point shall not be less than 10% of the motor rated full load torque.

Motor with auto-transformer starting shall be with 50% rated voltage across its winding and without changing to its final connection, and shall run to at least 90% of its synchronous speed within 10 seconds.

Power Rating

Motors shall be capable of operating continuously at any voltage in the range 90-110% of rated voltage and shall have power output of not less than 120% of the maximum power absorbed by the driven machines.

Transient Recovery

Motors shall be capable of recovering normal operation in the event of a system disturbance causing temporary loss of supply voltage for periods of up to 0.2 seconds (fault clearance-time) followed by a sudden restoration to 80% rated voltage. At this voltage the motors shall then be capable of accelerating to ultimate recovery under the most arduous load conditions.

Enclosure

For open type motor drive, the enclosure shall have the degree of protection of minimum IP 44 unless otherwise specified. Dimensions and frame number of motors shall comply with IEC 60072A.
The motor frame shall be designed to facilitate easy removal of rotor assembly and to permit access from both motor ends for cleaning and rewinding of the stator winding and replacement of the complete stator core assembly.

The motor shall be provided with suitable arrangement to facilitate lifting and handling during erection and overhaul.

C7.8.3 Thermal Insulation & Characteristics

The motor windings and accessories shall be designed for Class F insulation with Class B maximum temperature limit to BS EN 60034-1.

Natural rubber insulated cables shall not be used between the stator windings and motor terminals.

C7.8.4 Motor Stators & Windings

The motor winding insulation shall withstand voltage stress caused by switching of motor starter using SF₆ circuit breaker, vacuum circuit breaker or vacuum contactor.

Motors shall be designed to permit high voltage tests in accordance with BS EN 60034-1 to be conducted after erection on site.

End windings shall be rigidly braced to prevent their movement at the specified service duty.

The insulation system of stator windings shall be of the resin-rich type or the vacuum pressure impregnated type. Windings shall be given a surface treatment where necessary to prevent deterioration resulting from adverse environmental conditions and for corona shield.

Winding coils shall be of the pre-formed type. Random-wound type windings and hair-pin type windings are not acceptable. Stator slots shall be of the open type to facilitate easy insertion of replacement windings.

C7.8.5 Rotor

Unless otherwise specified, the rotor shall have cage type copper/copper alloy winding.

The limits of vibration shall comply with IEC 60034-14 or BS EN 60034-14 as appropriate.

The rotor shall be dynamically balanced at its rated speed or a speed not less than 600 rpm to confirm that vibration levels are within the specified limit. Means for fixing balancing weights in-situ shall be provided at both ends of the rotor without the need to dismantle the motor for balancing on site.
For motors of 750 kW rating and above or where the induced shaft voltage exceeds 0.15V, an insulated bearing arrangement shall be provided. Where such provision is made, all motor bearings shall be insulated from the stator frame and a removable earth bonding link shall be provided at the driving end to facilitate insulation tests. Oil and water pipes etc. where fitted shall be insulated to prevent a current return path through the bearings of the motor shaft. Care shall be taken to ensure that any insulation is not short circuited by the application of electrically conducting paints or fixing clips.

C7.8.6 Bearings

(a) General

Bearings shall be exclusively of metric sizes.

Unless otherwise specified or approved, bearings for horizontal motors shall be provided in accordance with Table C7.8.6 below.

Table C7.8.6 Type of Bearing

<table>
<thead>
<tr>
<th>Number of Poles</th>
<th>Motor Rating</th>
<th>Types of Bearing</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Above 500 kW</td>
<td>Plain</td>
</tr>
<tr>
<td></td>
<td>Up to 500 kW</td>
<td>Rolling</td>
</tr>
<tr>
<td>6 or more</td>
<td>Above 750 kW</td>
<td>Plain</td>
</tr>
<tr>
<td></td>
<td>Up to 750 kW</td>
<td>Rolling</td>
</tr>
</tbody>
</table>

The motor manufacturer shall examine the external axial and radial load imposed from the shaft and the driven device in the selection of the type of bearing to be used. Where damage is likely to occur to rolling bearings due to thrust load or stationary vibration, plain type bearings shall be preferred. Consideration shall also be given to bearing service life, noise, losses and maintenance convenience in the selection of bearings. Where rolling type bearing is selected to be used, the manufacturer shall provide calculation to verify that the L10 life of bearing is not less than 50,000 hours at the most onerous operating conditions.

Bearings shall be easily accessible for inspection and shall be liberally rated to ensure cool, even running. Bearings shall be suitable for reverse rotation at 150% of the normal running speed.

Motor bearings supplied shall be prevented from damage by any stray currents as detailed in Sub-section C7.9.5.

Protective and auxiliary equipment applicable as per Sub-section C7.8.11(b) and C7.8.11(c) shall be provided for bearings.

(b) Plain Type Bearings

Plain type bearings shall be self-lubricated. The lubrication oil shall be water-cooled unless otherwise specified. The cooler
shall be such as to avoid any electrolytic action or corrosion. Bearings shall be designed to exclude the ingress of dust and water and adequately sealed to prevent leakage of oil.

The water pipes shall not run over or adjacent to the HV terminal boxes and shall not impede access to the bearing for inspection. The initial filling of bearing lubricating oil shall be supplied and delivered in an oil drum.

Bearings shall be provided with a filling hole, an air breather, an accessible drain plug and a clearly visible oil level indicator to show oil levels during running and at standstill. Sight level indicators of the type fitted externally to the bearing shall be designed to prevent rotation about the gland connection.

Besides the normal running operation, the lubrication shall also be adequate during starting and running down periods.

The bearing design shall avoid oil being drawn into the winding through the shaft by centrifugal force or the effect of ventilation fan.

The bearing mounting bracket assembly shall be capable of completely detached from the stator, viz. no welding to the stator frame shall be permitted.

Bearing pads shall be self aligning in design, and shall not require any jacking screws for adjustment.

(c) Rolling Type Bearings

Rolling type bearings shall be adequately lubricated by grease and sealed against leakage of lubricant along the shaft. Construction shall be such that bearings can be dismantled and reassembled without risk of damage.

The bearing assembly shall be designed to prevent the entry of dust or water. It shall be provided with a separate grease nipple to serve each lubricating point and a grease relief device such that when the motor runs at its rated speed any surplus grease is ejected out of the bearing casing to a separate container.

Housings for ball/roller bearings shall be packed with approved lithium-based grease at the time of assembly. The required relubrication interval shall be more than 4,000 hours.

Grease nipples, oil cups and dip sticks shall be readily accessible without removal of guarding. Where necessary for accessibility, nipples shall be remotely mounted at a point as near as is practicable to the lubrication point.
A motor bedplate/foundation block shall be provided unless the motor is to be mounted on the soleplate of the compressor.

C7.8.8 Provision for Cabling and Termination

(a) Cabling Provision at Bedplates

Provision shall be made in the steel bedplate where necessary to facilitate straight run of cable to the bottom of the motor cable terminal box.

(b) Cabling Provision at Cable Boxes

Unless otherwise specified or approved, the cable terminal box for the motor shall be positioned at the side of the motor. Cable entry shall be from below for all box types unless otherwise specified.

An earthing terminal with the same current carrying capacity as the line terminals with the minimum size suitable for 25 x 6 mm copper strip shall be provided. A tapped hole with screw external to the cable box would be acceptable.

Permanent terminal marking and direction of rotation in accordance with BS 4999 Part 108 shall be provided in the cable boxes.

(c) Cabling Provision at Motor Casing

The terminal leads from cable box terminals or connectors to the windings for a distance of 150 mm beyond their point of entry into the motor frame, shall be adequately braced to withstand the forces produced by maximum fault current.

The phase windings shall be accessible for testing. For this purpose, neutral leads shall be brought out to a separate star-point terminal box and shorted with an insulated copper bar of cross-sectional area not less than the conductor of the terminal lead.

Studs shall be so fixed as to prevent the terminal leads from turning when the nuts are tightened down. Means shall be provided to prevent slackening of cable connections due to vibration.

(d) Motor Supply Cables

Motor terminations shall be suitable for connection of high voltage power supply cables which shall be cross linked polyethylene insulated, PVC-sheathed, galvanised steel wire and PVC covered XLPE/SWA/PVC copper cables as specified in Sub-section C7.12.
(e) Clearances and Creepage Distances

Electrical clearance and creepage distances shall comply with Table C7.8.8(e) below. These clearance and creepage distances shall also apply to terminals or connectors which have to be insulated on site, and shall apply even though the terminals or connectors are fully insulated, but are not intended to apply to permanently insulated conductors.

<table>
<thead>
<tr>
<th>Rated Voltage</th>
<th>Minimum Clearance</th>
<th>Minimum Creepage Distances over Bushings and Surfaces Resistant</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>To Earth</td>
<td>Between Phases</td>
</tr>
<tr>
<td>kV</td>
<td>mm</td>
<td>mm</td>
</tr>
<tr>
<td>3.3</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>6.6</td>
<td>63</td>
<td>90</td>
</tr>
<tr>
<td>11</td>
<td>75</td>
<td>125</td>
</tr>
</tbody>
</table>

C7.8.9 Motor Termination Boxes

(a) Construction

Cable boxes for motor power supply shall be of a type fault-tested design as follows:

3.3 kV - Phase-insulated pressure relief post type

6.6 kV, 11 kV - phase-segregated containment pressure relief post type.

The cable box for motor line connections shall each comprise a sealing chamber and an air insulated termination chamber bolted together, of degree of protection to IP 56. Sealing chamber is not required for the stator winding star point termination box.

Termination boxes shall be fabricated from mild steel of a minimum of 6 mm thickness. Cast iron boxes shall not be accepted.

The termination chamber shall be bolted to the motor casing such that its sides are vertical, with high tensile steel studs and nuts. The cable sealing chamber shall be fixed to the bottom of the termination chamber by means of high tensile steel bolts or studs and nuts.

The cable sealing chamber for XLPE cable shall be of the dry type suitable for cable termination in heat shrinkable sleeving.
Sealing chamber shall be fitted with a horizontal gland plate suitable for bottom cable entry.

The termination chamber shall have an insulated assembly and be fitted with 3 stud terminals in insulating mouldings of epoxy resin, glass fibre, polyester or approved similar material. Porcelain insulators shall not be used. Cable-coupler type terminals shall not be acceptable.

Front access detachable cover plates shall be fixed by studs and nuts. Separate plates shall be supplied for sealing and termination chambers.

Joints shall be machined flat and fitted with neoprene rubber gaskets.

(b) Termination Box Auxiliaries

Brass cable glands shall be provided for motor supply cables. Cable lugs shall be supplied for the motor supply cable. Unless special lugs are used in the short circuit type test, cable lug shall be of the compression type manufactured from tin-plated seamless copper tubing with single bolt palm terminal. The cable lug shall be type-tested to BS 4579 Part 1 with dimensions conforming to BS 91 Table 2.

C7.8.10 Markings and Data Plates

An instruction and a data plate, of stainless steel, brass or other approved non-tarnishing metal shall be provided. The instruction plate shall give the connections and phase rotation for the required direction of rotation. The required direction of rotation shall be marked on the motor.

The data plate shall be stamped with the information required by BS EN 60034-1. Data plates on which the above required information is only painted will not be accepted.

The motor serial number shall be stamped with metal dies on the driving end shaft face of the motor in addition to being stamped on the stator.

C7.8.11 Temperature Detectors for Motor Protection

(a) Embedded Temperature Detectors (ETD)

Unless otherwise specified, embedded temperature detectors of linear characteristics, e.g. thermocouple or resistance thermometer, and complete with monitoring unit shall be provided to offer protection against over-heating on load and stalling of the motor. Resistance temperature detector (RTD) shall comply with Grade 2 of BS EN 60751 or IEC 60751.

At least two detectors of the same characteristics suitably embedded in the stator shall be installed, positioned at points at
which the highest temperatures are likely to occur, e.g. one
detector between coil sides within the slots, one detector under
the coils at the bottom of the slots and one detector between the
coils and slot wedges. Detector leads shall be wired to an
auxiliary cable box such that any ETD may be isolated for
testing.

The ETD monitoring unit for each motor shall have the
following features: -

(i) Alarm contacts to operate at a temperature of 120ºC
which is adjustable for individual detecting elements.

(ii) Trip contacts to operate at a temperature of 140ºC which
is adjustable for individual detecting elements.

(iii) A common digital temperature gauge and selection
buttons for reading the winding temperatures of the
individual detecting elements.

(b) Temperature Detectors for Bearings

A temperature detector shall be installed for each bearing for
high temperature alarm and trip operation.

Unless recommended otherwise by the motor manufacturer,
alarms detectors shall operate 10ºC lower than the trip detectors.

Insulated thermometer pockets shall be provided to enable easy
insertion or removal of a temperature detector. Dial type
thermometers or digital indicators, with independently adjustable
alarm and trip contacts, shall be provided at the motor control
switchboard to monitor the bearing temperatures. Contacts shall
be arranged to close for alarm indication or tripping and shall be
so arranged that the operation of the alarm or tripping may be
checked manually.

(c) Bearing Coolant Failure Detector

Where water cooled bearings are used a flow failure detector
shall be provided.

Suitable timers and relays shall be provided to obviate any false
alarm during the starting up of the motor set or on flow surges.

C7.9 HIGH VOLTAGE - MOTOR CONTROL SWITCHBOARDS

C7.9.1 General Requirements

(a) The motor control switchboards shall be of the single busbar,
indoor air-insulated, metalclad type formed into complete
switchboards. The high voltage switchgear and switchboards
shall comply with IEC 60056 and BS EN 60298 or IEC 60298 respectively.

(b) The power to the high voltage motors shall be distributed from the high voltage motor control switchboards through the motor starters incorporated in the switchboards. The control switchboards shall contain a motor starter for each motor set.

(c) The switchboards shall, but not be limited to, include the following equipment :-

(i) Incoming circuit breaker  
(ii) Motor starter  
(iii) Overcurrent and earth leakage protective relays and devices  
(iv) Motor temperature monitoring unit  
(v) Motor bearing temperature gauges  
(vi) Emergency stop button  
(vii) Local controls for ancillary equipment  
(viii) Sufficient terminals and cable glands for external cable connections  
(ix) Anti-condensation heater and associated thermostat  
(x) Isolators, fuses and other wiring ancillaries  
(xi) Power factor correction capacitors and controlgear

(d) Type test certificates shall be available for each rating of circuit breaker and switchboard to be supplied. The results of all type tests shall be recorded in type test reports containing sufficient data to prove compliance with the Specification. Type test certificates shall be issued preferably by the Association of Short-circuit Testing Authorities (ASTA) or N.V. tot Keuring van Elektrotechnische Materialen (KEMA). Test certificates issued by other organisations will only be accepted if the testing authority is established as being of equal standard as ASTA or KEMA.

(e) General Design Information

Table C7.9.1(e) General design information

<table>
<thead>
<tr>
<th>Rated operational voltage</th>
<th>3.3 kV, 6.6 kV or 11 kV as specified, 3-phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earthing of system</td>
<td>Solid</td>
</tr>
<tr>
<td>System frequency</td>
<td>50 Hz</td>
</tr>
<tr>
<td>Installation type</td>
<td>Indoor</td>
</tr>
<tr>
<td>Power supply for circuit breaker</td>
<td>Operation, controls and protection</td>
</tr>
<tr>
<td>Power supply for auxiliary Equipment</td>
<td>220V ac ± 10% 1-phase 50 Hz</td>
</tr>
<tr>
<td>Degree of protection</td>
<td>IP 31</td>
</tr>
<tr>
<td>Insulation class</td>
<td>Class B</td>
</tr>
</tbody>
</table>
The switchgear and cubicles for high voltage switchboard shall comply, in particular, with the following Standards where appropriate:

Table C7.9.1(f) Standards

<table>
<thead>
<tr>
<th>Standards</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BS EN 60269 or IEC 60269</td>
<td>Cartridge fuses for voltages up to and including 1000V a.c. and 1500V d.c.</td>
</tr>
<tr>
<td>BS EN 60051 or IEC 60051</td>
<td>Direct acting indicating electrical measuring instruments and their accessories</td>
</tr>
<tr>
<td>BS EN 60255 or IEC 60255</td>
<td>Electrical protective relays</td>
</tr>
<tr>
<td>BS EN 60282-1 or IEC 60282-1</td>
<td>Fuses for voltages exceeding 1000V a.c.</td>
</tr>
<tr>
<td>IEC 60185</td>
<td>Current transformers</td>
</tr>
<tr>
<td>IEC 60186</td>
<td>Voltage transformers</td>
</tr>
<tr>
<td>BS EN 60947-5-1 or IEC 947-5-1</td>
<td>Control Switches</td>
</tr>
<tr>
<td>IEC 60376</td>
<td>Sulphur hexafluoride for electrical equipment</td>
</tr>
<tr>
<td>BS EN 60298 or IEC 60298</td>
<td>A/C metal-enclosed switchgear and controlgear of rated voltage above 1 kV and up to and including 52 kV</td>
</tr>
<tr>
<td>IEC 60056</td>
<td>A/C circuit breakers for rated voltage above 1 kV</td>
</tr>
<tr>
<td>BS EN 60521 or IEC 60521</td>
<td>Electricity meters</td>
</tr>
<tr>
<td>BS 6231</td>
<td>PVC-insulated cables for switchgear and controlgear wiring</td>
</tr>
<tr>
<td>BS EN 60694 or IEC 60694</td>
<td>High-voltage switchgear and controlgear standards</td>
</tr>
</tbody>
</table>

C7.9.2 General Construction

The switchboards shall consist of dust and vermin-proof cubicles segregated into single or multi-tier compartments. They shall be made from sheet steel of 2.5 mm minimum thickness.

The edges of hinged panel doors shall have deep return flanges for rigidity and fitting of gaskets. Gaskets shall be of neoprene or rubber, continuous without joints around corners and suitably arranged to minimise the transmission of vibration and to prevent the entry of dust. Hinged panel doors shall be fitted with chromium plated solid rod type detachable hinges and chromium plated car door type lockable handles.

Forced ventilation shall not be allowed under an ambient temperature of 40°C. Ventilating grills, where required, shall not be located on top of a panel.

Each switchgear unit shall comprise three main portions:
(a) Separate chambers at the top of the switchboard housing the busbars, current transformers and voltage transformers, and shall be accessible through bolted covers only,

(b) A compartment housing the relays and instruments,

(c) A moving portion comprising a carriage complete with circuit breaker. The circuit breaker shall preferably be arranged for vertical isolation from the busbars.

The circuit breaker compartment shall be accessible through a hinged door fitted with a glazed window for viewing the circuit breaker mechanical status indicators.

The relay and instrument compartment shall be located at the front of each switchgear unit and shall be provided with a hinged door for access to the internal wiring and terminals. Moulded gaskets of non-aging material shall be used to provide close sealing. The height of the instrument panel above floor level shall not exceed 2400 mm. All panels constituting a complete switchboard shall be of equal height.

Bolted-on rear and top covers shall be designed to gain access to individual circuits without exposing other circuits which may be alive. Switchboards shall not be located across floor expansion joints.

Before steelworks is painted, it shall be treated and degreased by an approved method such as grit blasting to ISO 8501-1 or chemical pickling and an approved anti-rusting priming coat applied. The panels shall be externally finished in semi-gloss stoved enamel or cellulose to a colour to be approved by the Architect.

C7.9.3 Primary Busbars and Connections

Primary busbars and connections between the several pieces of apparatus forming the equipment of a switchboard shall be of high conductivity copper to BS 1433. Construction, marking and arrangement of busbars, connections and auxiliary wiring shall be to BS EN 60298 or IEC 60298 and BS 159.

Primary busbars shall be contained in a separate compartments within the switchboard and access shall be possible only by means of bolted-on sheet steel covers which shall clearly be marked 'BUSBARS'. Busbars and busbar connections shall not be exposed when covers and doors are opened for access to the remainder of the switchgear. Busbars shall be readily extensible.

Each phase conductor of the primary busbars including all through joints and tapping connections shall, in addition to being spaced at such intervals as to give the necessary air clearance for the voltage rating, shall be epoxy encapsulated solid copper bars. Joints shall be insulated with moulded removable insulated covers. Taping shall not be accepted.
Primary busbars, connections and their supports shall be capable of carrying the short-time current associated with their short-circuit ratings for a period of 3 seconds.

Where busbar supports use insulation of moulded or resin bonded material, it shall have a durable anti-hygroscopic surface finish with high anti-tracking properties.

The connections from busbars in individual units shall have a continuous current rating of not less than that of the equipment comprising the unit.

At all points where connections or joints occur, the busbars and connecting pieces shall be tinned or silver-plated. The resistance of any length of conductor containing a joint shall not be greater than that of an equal length without a joint.

Jointing of sections of busbars shall be done by mechanical means. Soldered, braced, welded or riveted joints shall not be used in busbars. Jointing faces of copper conductors shall be tinned or silver plated, or applied with other approved treatment to maintain effective conductivity of the joint. All necessary busbar jointing bolts, nuts, and fixing accessories shall be provided. The recommended torque for tightening the bolts shall be stated in the maintenance manual.

Primary busbars and connections shall be clearly marked and shall be displaced for standard phase sequence Red (R), Yellow (Y) and Blue (B) counting from front to rear, top to bottom, or left to right as viewed from the switching device operating mechanism side to BS EN 60298 or IEC 60298.

C7.9.4 Circuit Breakers

(a) General

Unless otherwise specified, the 11 kV circuit breaker units shall be of the vacuum type complying with IEC 60056, and the 3.3 kV or 6.6 kV circuit breaker units shall be of the vacuum type or the sulphur hexafluoride (SF₆) type complying with IEC 60056. They shall be of a design with vertical isolation, horizontal withdrawal facilities.

The moving portion of each circuit breaker unit shall consist of a three-pole circuit breaker with operating mechanism, primary and secondary disconnecting devices, auxiliary switches, position indicators and the necessary control wiring all mounted on a substantial steel framework. The framework and all metal part of the moving portion apart from current carrying parts, shall be solidly earthed via the fixed portion. The earthing of the moving portion shall be to the approval of the Architect. Means of registration shall be provided so that circuit breakers may be readily placed and secured in the correct position in the fixed portion.
Circuit breakers of the same current and voltage rating shall be fully interchangeable with one another. Means shall be provided to prevent circuit breakers from being placed into fixed housings of different ratings. This device shall also prevent damage to isolating and other contacts.

(b) Vacuum Circuit Breakers

For vacuum circuit breakers, means of confirming the validity of vacuum by the occurrence of flash-over when a voltage is applied between the vacuum interrupter contacts shall be included in the maintenance tools. Vacuum leakage shall be monitored to initiate an alarm and it shall not be possible to close a circuit breaker when vacuum leakage is serious enough to threaten safe operation of the switchgear.

Vacuum circuit breakers for motor circuits shall incorporate surge suppressers to minimise the effects of switching transient voltage on the motor insulation.

(c) SF₆ circuit breakers

A pressure switch shall be provided on the SF₆ gas compartment to monitor the gas pressure. The system of gas monitoring shall be temperature compensated.

Alarm and lockout feature shall be incorporated. Alarm signal shall be initiated and the breaker shall be inhibited from closing whenever the gas pressure drops below a preset level. The circuit breaker shall be prevented from operation. Means shall be provided in the gas compartment for the connection of service equipment and for the topping up of the gas.

The circuit breaker shall be suitable to interrupt its rated normal current with SF₆ gas at atmospheric pressure. The sealing of the gas compartment shall be designed so that there is no need for the SF₆ gas to be replenished within reasonable periods. The gas leakage shall not exceed 1% per annum at site ambient temperature.

An external contact indicator shall be provided to check the extent of contact wear. Means shall also be provided to allow access to the contacts of the interrupter units for necessary inspection and maintenance. All contact assemblies shall be replaceable. Safeguards shall be provided to prevent incorrect replacement of contacts.

The designed electrical and mechanical life shall be at least 5,000 and 10,000 cycles respectively. The circuit breaker shall be capable of undergoing 40 cycles of fault breaking operations at 50% rated short-circuit breaking current or equivalent without any need of opening up the tank for inspection or contact replacement.
Instructions for post-fault maintenance, gas top-up contact and seal replacement shall be clearly detailed in the manual.

(d) Operating Mechanisms

The circuit breaker operating mechanism shall be of the following types as specified: -

- Stored energy operation by means of a manually charged spring with mechanical release.
- Stored energy operation by means of a motor-charged spring with manual and electrical release.
- Solenoid operated.

The mechanism shall be of the trip free type so that the circuit breaker shall be free to open during the closing operation immediately its tripping device operates. The circuit breaker shall be capable of closing fully and latching against its rated making current.

Spring operated mechanisms shall have the following additional measures: -

- If the circuit breaker is opened and the springs charged the circuit breaker shall be able to be closed and then tripped.
- If the circuit breaker is closed and the springs charged there shall be sufficient energy to trip, close and then trip the circuit breaker.
- Mechanical indication and an auxiliary switch for remote electrical indication shall be provided to indicate the state of the springs.
- Motor charged mechanisms shall be provided with means for charging the springs by hand, and also a shrouded push button for releasing the springs. An electrical release coil shall also be provided.
- Under normal operation, motor recharging of the operating springs shall commence immediately and automatically upon completion of each circuit breaker closing operation. The time required for spring recharged shall not exceed 30 seconds.
- It shall not be possible to close a circuit breaker, fitted with a motor charged closing mechanism, whilst the spring is being charged. It shall be necessary for the spring to be fully charged and the associated charging
mechanism fully prepared for closing before it can be released to close the circuit breaker.

All circuit breaker operating mechanism shall be fitted with an electrical shunt trip release coil and in addition a mechanical hand tripping device.

The electrical tripping and closing devices shall be suitable for operation from a 110 V d.c. battery supply and but shall operate continuously with their coils at an ambient temperature of 40°C, over a voltage range as follow: -

- Closing solenoid 80 to 120% of nominal voltage
- Spring charging motor 80 to 110% of nominal voltage
- Closing release coil 80 to 110% of nominal voltage
- Shunt trip release coil 50 to 120% of nominal voltage

except that under battery boost charge conditions when they shall be capable of operating at rated output and 130% of nominal voltage for up to two hours.

All operating coils for use on the d.c. supply shall be connected so that failure of insulation to earth does not cause the coil to become energised.

Tripping and closing circuits shall be provided with a fuse in each pole on each unit and shall be independent of each other on all other circuits.

Approved, positively driven mechanically operated indicating devices shall be provided to indicate whether a circuit breaker is in the open or closed service, isolated or earthed position.

(e) Isolating Devices

All circuit breakers shall be connected to their associated busbars and cables through isolating devices of an approved design to IEC 60056 and BS EN 60298 or IEC 60298 which shall be arranged for operation whilst the main circuit is live but no current passing.

The design shall be such that it is impossible for the isolating devices to be opened by forces due to current in the primary circuit and shall be interlocked with the circuit breaker so that it is impossible to make or break current with the isolating device. Attempted isolation shall not trip the circuit breaker.

When isolation is effected by withdrawal of the circuit breaker, provision shall be made for positively locating the circuit breaker
in the service, isolated and, earthing positions. Stops shall be provided to prevent over-travel and each position shall be clearly indicated. Preferably a mechanical selector mechanism shall be utilised such that when a particular position is selected, it is impossible to locate the circuit breaker in any other position.

Isolating devices shall incorporate self-aligning contacts, the fixed contact of which shall be such that access can readily be obtained for maintenance purposes.

(f) Overcurrent and Earth Fault Protection

All circuit breakers other than those used for controlling the incoming supply, shall have overcurrent tripping facilities to give time delay overload current protection and instantaneous short circuit interruption. The time-current characteristics shall be submitted for inspection. Shunt trip coils operated by power supply from the mains shall not be used.

For circuit breakers controlling the incoming supply to the Switchboard, the circuit protection shall be provided by the following devices: -

- Overcurrent Protection Relay
- Earth Fault Relay
- Shunt-Trip Release

It shall be operated by a DC supply of 110 V obtained from the secondary batteries complete with battery charger, etc. of suitable rating

(g) Safety Shutters

Metal shutter shall be provided to completely shroud fixed isolating contacts of the circuit breaker busbar and feeder circuits. These shutters shall be opened and closed automatically by the movement of the circuit breaker carriage and shall prevent access to fixed isolating contacts when the circuit breaker is withdrawn.

The shutters for fixed isolating contacts connected to busbars and cables shall have independent operating mechanisms. All shutters shall have painted labels indicating whether they are busbar or feeder shutters.

To facilitate high voltage and current injection testing via isolating contacts, a device shall be provided for fixing, but not locking, shutters in the open position and for releasing them to the closed position. This device shall be arranged to be disengaged as soon as the circuit breaker is pushed into the service position to ensure that the automatic features of the shutters are restored.
Self-aligning plug and socket isolating devices shall be provided for all auxiliary circuits. The position of these devices shall be such that individual circuits on different units are in the same relative physical positions.

(h) Interlocking Gear

Interlocks shall be of the mechanical or key operated type and shall be provided to prevent the following operations:

(i) A moving portion from being withdrawn from or inserted into the isolating contacts when the circuit breaker is closed.

(ii) The closing of the circuit breaker unless the movable portion is correctly plugged in or isolated from the equipment.

(iii) The movable portion being withdrawn or replaced unless the circuit breaker is isolated and in the appropriate position.

(iv) The movable portion being plugged in without the circuit breaker tank in position.

(v) The circuit breaker being closed in the 'SERVICE' or 'EARTH' location without completing the appropriate auxiliary circuits.

(vi) To apply an earth to busbars until all circuit breakers which can feed the busbars, are locked open.

When key interlocking is employed, any attempt to remove the trapped key shall not cause closing or opening of the associated equipment.

Where a circuit breaker is fitted with means for mechanical or electrical operation, interlocks shall be provided so that it is impossible for the mechanical and electrical devices to operate simultaneously.

The earthing devices shall be provided with interlocks to ensure correct operation in conjunction with the associated circuit breaker.

In the case of circuit breaker earthing, the electrical tripping of the circuit breaker shall be rendered inoperative during earthing operations both when closing and when closed in the earthed position. It shall not be possible to return to the service position and close the circuit breaker until the electrical tripping is again operative.
A mechanical key interlocking system shall be provided whereby it is not possible to apply an earth to busbars until all circuit breakers which can feed the busbar are locked open. In addition it shall not be possible to earth busbars and cable circuit at the same time by means of the same circuit breaker.

In addition to safety interlocking which is integral to a circuit breaker unit to prevent wrong or dangerous operation of the unit itself, further interlocking shall be provided.

In general, interlocking shall be electrically isolating the closing contactor coil circuit of a circuit breaker being interrupted unless the necessary conditions for closure are met. The interlocking shall be designed on a system wide basis to ensure that subsequent operation of a non-interlocked circuit breaker does not result in a set of conditions that would contradict the original 'permission to close'.

(i) Interlocking Circuits

Where interlocking over a distance is required, two independent criteria shall be used, such as absence of a voltage and remote feeding circuit breaker open. Indication of the remote condition shall be by single purpose circuit, care being taken that the conductors used are adequately screened and shielded to minimise both transverse and longitudinal voltages resulting from electromagnetic induction and differences in earth potential. The cable containing cores for interlocking circuits shall be separate from all other multi-core cables.

All interlocking circuits shall be of the 'go and return' design, and in no instance will interconnection of batteries in different locations be permitted.

Where a circuit breaker is capable of manual operation in addition to electrical operation, except where such manual operation is possible only for maintenance purposes, key-operated interlocking shall additionally be provided, operative only in the instance of manual operation.

Electrical interlocks on withdrawable equipment shall be arranged so that when withdrawn, the equipment operation will be independent of the remote interlocking contacts. In addition, the interlocks shall be such that, when the equipment is withdrawn, the interlocking of associated apparatus is correct, and operation of the equipment in the withdrawn position will have no effect.

(j) Locking Facilities

Locking facilities shall be provided so that the circuit breaker can be prevented from being closed when it is open and from being manually tripped when it is closed. These facilities shall not
require the fitting of any loose components prior to the insertion of the single padlock required. It shall not be possible, without the aid of tools, to gain access to the tripping toggle or any part of the mechanisms which would permit defeat of the locking of the manual trip. It shall not be possible to lock mechanically the trip mechanisms so as to render inoperative the electrical tripping.

In addition, the following padlocking facilities shall also be included:

(i) Selector mechanisms on circuit breaker isolated and service positions.

(ii) Safety shutters on primary contact isolating orifices in closed position.

All switchboard access doors, other than those which are interlocked with a switching device, shall be provided with an integral type locking facility.

C7.9.5 Earthing and Earthing Devices

All metal parts other than those forming part of an electrical circuit shall be connected in an approved manner to a hard drawn, high conductivity copper earth busbar which shall run the full length of, and be bolted to, the main frame of the switchboard. At the position where joints occur, the earth busbar shall be tinned. The earth busbar shall be rated to carry currents equal in magnitude and duration to that associated with the short circuit rating of the equipment.

The design and construction of the equipment shall be such that all metal parts, other than the current carrying parts, or the withdrawal equipment are earthed before the primary connections are made.

Metal cases supports and bases of all instruments, relays or other associated components mounted on the switchgear shall be connected to the earth busbar by conductors of not less than 2.5 mm² cross-sectional area.

When components are provided for mounting separately each shall be provided with an earthing terminal of not less than 30 mm² cross sectional area.

Earthing devices shall be provided on all circuit breaker units whereby the circuit can be earthed. With the circuit earthed, shutters over unearthed fixed main isolating contacts shall be closed.

Busbar earthing facilities shall be provided on selected circuits of each separate switchboard, these circuits shall be agreed with the Architect.

Circuit and busbar earthing shall be of the transfer circuit breaker arrangement and it is preferred that the facilities shall be integral in the
design and construction of the switchgear. Earthing devices for fitting to the circuit breakers are acceptable but they shall be supplied in a separate container together with a set of instructions for fitting and operating the equipment. Designs effecting earthing by means of a separate fault-making switch are not acceptable.

Feeder and busbar earthing devices shall have a short circuit rating equal to that of their associated circuit breaker.

Padlocking facilities shall be provided for the purpose of preventing inadvertent earthing.

Labeling shall be provided to show whether the equipment is prepared for 'SERVICE', 'BUSBAR EARTH' or 'CIRCUIT EARTH'. Such indication shall be visible from the front of the equipment at all times. Duplicate labels in Chinese and English shall be provided.

C7.9.6 Testing Facilities

All circuit breaker units shall be provided with facilities to enable applied high voltage tests to be carried out.

Provision shall also be made for temporarily completing the auxiliary circuits when the circuit breaker is isolated and if applicable, withdrawn to enable the functioning of the circuit breaker to be tested.

When current transformers and protective relays are fitted, facilities shall be provided for primary and secondary injection tests to be carried out.

These facilities shall preferably be such that wires and connections need not be disconnected for the tests to be carried out.

C7.9.7 Mechanical Indication

Indication shall be provided to clearly indicate whether a circuit breaker is in the open or closed service, isolated or earthed position.

Positively driven mechanical indicating devices shall be provided on all equipment to indicate the following where applicable: -

(a) Circuit breaker 'OPEN' or 'CLOSED'
(b) Circuit breaker 'SPRING CHARGED' or 'SPRING FREE'

C7.9.8 Auxiliary Switches

Auxiliary switches of the double-break type and positively driven in both directions shall be provided on all circuit breakers and isolators for indication, control and interlocking.

Auxiliary switches shall be strong, have a positive wiping action when closing and shall be mounted in an accessible position clear of operating mechanisms.
They shall be designed to make, break and carry, without undue heating, the current of their associated circuit. Auxiliary switches shall be rated for 10A operational current, and shall be capable of breaking at least 2A at 110 V d.c.

No less than eight spare auxiliary switches shall be provided with each circuit breaker and no less than four with each isolator. Each spare contact shall be readily changeable from normally open to normally closed and vice versa. All auxiliary switches shall be wired up (via secondary disconnecting devices if on withdrawable equipment) to a terminal board on the front of the fixed portion, arranged in the same sequence for each individual unit of the same type.

C7.9.9 Anti-Condensation Heaters

Anti-condensation heaters of an approved type shall be provided inside each cubicle. They shall be thermostatically controlled and shall operate at black heat and shall be shrouded and located so as not to cause injury to personnel or damage to equipment. The heaters shall be controlled from a double-pole miniature circuit breaker, with a lamp to indicate 'cubicle heaters on'. The circuit breaker and indicating lamp shall be mounted externally at one end of the switchboard. The heaters shall operate from 220 V 50 Hz single phase a.c. supply.

C7.9.10 Current Transformers

Current transformers shall comply with IEC 60185 and shall be suitable for the operation of protective gear, instruments and/or metering equipment.

Current transformers shall be of the epoxy resin encapsulated type and shall have necessary output to operate the connected protective devices or instruments.

The primary windings shall have a short time current rating not less than that specified for the associated circuit breaker. The rated secondary current shall be 1A or 5A.

Protection current transformers shall be of Class 10P accuracy or better. The product of rated accuracy limit factor and rated output of the protection current transformer shall not be less than 10 times the rated burden of the trip circuit including the relays, connection leads and overcurrent release where applicable.

Measurement current transformers shall be suitably rated and have accuracy Class of 3 for use with ammeters, and Class 1 for other types of meters.

The polarity of the primary and secondary windings of each current transformer shall be clearly indicated and in addition labels shall be fitted in a readily accessible position to indicate the ratio, class and duty of each transformer. The current transformer particulars as specified in IEC
60185 shall be given on an accessible plate mounted external to the current transformer.

All connections from secondary windings shall be brought out and taken by means of separate insulated leads to a terminal board mounted in an accessible position. Where multi-ratio secondary windings are required, a label shall be provided at the secondary terminal board clearly indicating the connections required for each ratio.

Current transformers for indication or metering shall have their secondary windings earthed at the switchgear. The secondary windings of current transformer for protection shall be earthed at the panel which accommodates the associated relay. The earth connection shall be made via a removable link.

Each current transformer shall have a certified maximum rating of at least 1.2 times the rated current.

**C7.9.11 Voltage Transformers**

Voltage transformers shall comply with IEC 60186 and suitable for the operation of protective gear, voltage regulating equipment, instruments and/or metering. All voltage transformers shall be of the dry type with epoxy encapsulation. The rated output per phase at a power factor 0.8 lagging shall not be less than 100 VA. The rated voltage factor shall be 1.2. They shall have a measuring accuracy class of 0.5 and a protective accuracy class of 3P.

Voltage transformers shall be capable of carrying continuously without injurious heating 50% burden above their rated burden. The rated primary voltage of voltage transformers shall be the appropriate nominal system voltage.

Unless specified otherwise, voltage transformer primary windings shall be connected to the circuit side of the current transformers remote from the busbars so as to be included in the protected zone of the associated feeder.

The primary of a single phase voltage transformer shall be connected across Red and Yellow or A and B phases, unless otherwise approved. Red and Yellow phases shall be used in a synchronising scheme, unless otherwise approved.

Voltage transformers shall be capable of being connected and disconnected from the equipment whilst in service. Facilities for padlocking in the service position shall be provided. Where isolating is carried out by withdrawal, a set of shutters, capable of being padlocked, shall be provided to cover the stationary isolating contacts. The shutters shall operate automatically by positive driven drive actuated by movement of the voltage transformer assembly.

The primary windings shall preferably be connected via renewable fuses with current limiting features which shall be readily accessible with the
circuit alive and the secondary windings through fuses and links, labelled to indicate their function and phase colour, to the appropriate circuits.

For single phase voltage transformers, both ends of each secondary-winding shall be brought out to insulated links. For three phase voltage transformers, each phase end shall be brought out to fuses, and the neutral of the secondary winding shall be brought out to insulated links. The fuses and links shall then be brought out to insulated terminals located in a terminal box.

The primary and secondary fuses shall be capable of being removed and replaced when the circuit breaker is closed in the service position. Isolation of the primary fuses for this purpose shall be carried out, preferably by withdrawing the entire voltage transformer assembly. Additionally, it shall be possible to remove secondary fuses whilst the voltage transformer is padlocked in the service location.

For single phase units, separate earth links for each secondary winding shall be provided. Each of the neutral leads shall be connected together at a single point and earthed as close as possible to the voltage transformer.

Voltage transformer secondary windings shall be earthed at the switchgear through a link which can be removed for insulation testing.

Voltage transformers having the neutral point of their higher voltage windings earthed, shall be designed so that saturation of the core and dangerous over-heating arising therefrom shall not occur when 1.73 times normal voltage is applied to each winding for a period of 15 minutes.

Secondary circuits of voltage transformer shall not be parallel.

The secondary voltage connections to metering circuits shall be broken automatically when the circuit breaker is opened.

C7.9.12 Cables Boxes

Cable boxes shall be suitable for terminating the cables directly into the switchgear. The dimensions and terminal arrangements, together with details of air insulated heat-shrinkable elastomeric PCP cable termination, shall be submitted for approval by the Architect before manufacture.

All cable boxes shall be suitable for use with air insulated heat-shrinkable elastomeric PCP cable termination and shall be designed with joint faces which will ensure leak-free operation and exclude the entry of air, dust or moisture. The internal surfaces of cable boxes shall be cleaned of all scale and rust and after cleaning and priming, shall be finished with a hard setting paint compatible with the filling medium.

Where cable boxes are provided for three-core cables, the sweating sockets on the two outer phases shall be inclined towards the centre to
minimise bending of the cable cores. Where there is more than one core per phase, the socket block shall be so designed as to minimise bending of the cable cores, and spacer clips shall be incorporated.

All cable terminals shall be of adequate size to ensure no overheating takes place at rated current.

The insulators and fittings shall be unaffected by atmospheric and climatic conditions, ozone, acids or alkalis, dust deposits or rapid temperature changes likely to arise when operating in the specified site conditions and shall be designed so as to facilitate cleaning.

C7.9.13 Protective Relays

Unless otherwise specified, Sub-section C7.5.3 shall apply.

C7.9.14 Control and Timer Relays

Control and timer relays shall be of the plug-in type, rack mounted, provided with cable connection terminal and anchored by quick fastening vibration-proof devices. Timer shall be of the solid-state type with proven reliability.

C7.9.15 Indicating Instruments

Unless otherwise specified, Sub-section C7.5.3 shall apply.

C7.9.16 Labels and Warning Notice

Laminated 'Traffolyte' or similar labels of ample size shall be provided for each of the units on the switchboards engraved in English and Chinese characters. Labels shall be fixed by screws on the non-detachable parts of the panel at a height of 1350 mm or above.

During the progress of manufacture of the switchboard, a schedule of labels shall be submitted for approval by the Architect before engraving is carried out.

'Danger - H.V. Live Terminals' warning labels shall be attached to the access covers of the air insulated cable boxes, CT chambers and busbar, and shall be coloured red with white lettering in both English and Chinese characters.

In addition to automatic screening shutters and barriers, warning labels shall also be provided for all live parts, such as test terminal blocks.

C7.9.17 Ancillary Equipment

Battery charger/batteries system as specified in Sub-section C7.5.3 shall be provided for the proper functions of the switchgear in the switchboard.
The switchboard shall be supplied complete with one hydraulic operated handling device suitable for handling all sizes of air circuit breakers in the switchboard, and one set of portable earthing equipment for each main incoming air circuit breaker. Portable earthing leads will not be accepted as an alternative to the earthing equipment.

The switchboard shall be supplied complete with all operating handles, jigs, etc. required for the normal charging, closing, opening, racking in and out operations of all circuit breakers of the switchboard and shall be properly fixed in a neat manner on a board with brass hooks inside the main switch room where the switchboard is installed.

The switchboard shall be provided with two rubber mats of ribbed surface, complying to BS921, laid in front of and at the rear of the switchboard. The rubber mats shall be continuous sheets of 10 mm minimum thickness, each of the same length as the cubicle switchboard and a minimum width of not less than 1000 mm or the width of the space between the front or back of the switchboard to the adjacent wall.

C7.9.18 Operation Diagram

For high voltage switchboards with interlocking facility, a brief operation instruction of the switchboards together with a detailed schematic wiring diagram, listing out all the relevant switching steps and interlocks for commissioning/decommissioning of part or whole of the high voltage switchboards shall be provided in a framed, transparent perspex sheet mounted adjacent to the switchboards.

C7.10 HIGH VOLTAGE - AUTO-TRANSFORMERS

C7.10.1 General

The auto-transformers for the auto-transformer motor starters shall comply with the following specific requirements: -

(a) Type
- Indoor and floor mounted type for no breaking starting of squirrel cage 3-phase induction motor

(b) Standard
- BS EN 60076 or IEC 60076

(c) System Voltage
- 3.3 kV, 6.6kV or 11kV as specified

(d) Frequency
- 50 Hz

(e) Connections
- Auto-star for auto-transformer starting

(f) Insulation Level
- 45 kV peak impulse voltage for 1/50 microsecond

(g) Cooling
- Natural air cooled

(h) Tappings
- Off load tap changers with 60%, 75% and 85% of the line voltage to limit the starting current to 2.5 times of full load current
The auto-transformers shall be mounted on wheels to facilitate positioning and removal. The transformers shall be externally finished in semi-gloss stoved enamel or cellulose.

C7.10.2 Rating

The rating of the auto-transformer shall be designed to suit the starting duty of the motor. Motor starting time shall be taken as 10 seconds at 75% or higher taps and 15 seconds at 60% or lower taps unless otherwise specified in the Particular Specification.

C7.10.3 Insulation

(a) Insulation Medium

Unless otherwise specified, for 11 kV nominal voltage, oil-filled transformers are preferred. Epoxy resin encapsulated auto-transformers shall be preferred for nominal voltage up to 6.6 kV.

(b) Class

Oil immersed transformer windings shall be designed for Class E insulation for Class E operation.

Epoxy resin encapsulated transformer windings and live parts in air shall be designed for Class F or Class B insulation for Class B operation.

(c) Coordination of equipment insulation

Table C7.10.3(c) Coordination of Equipment Insulation

<table>
<thead>
<tr>
<th>Rated system voltage</th>
<th>12kV</th>
<th>7.2kV</th>
<th>3.6kV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal system voltage</td>
<td>11kV</td>
<td>6.6kV</td>
<td>3.3kV</td>
</tr>
<tr>
<td>Minimum impulse withstand voltage (1.2kV per micro-second)</td>
<td>75kV</td>
<td>60kV</td>
<td>40kV</td>
</tr>
<tr>
<td>Minimum power frequency withstand voltage (1 min)</td>
<td>28Hz</td>
<td>20Hz</td>
<td>10Hz</td>
</tr>
</tbody>
</table>

C7.10.4 Transformer Windings

All windings, terminals and connections shall be of copper. To protect windings against high humidity, the core shall be protected by a resin encasement which shall be resistant to moisture but elastic enough to withstand the expansion and contraction caused by the loading cycles.

Impregnation shall be carried out under vacuum to obviate the presence of any air bubbles. Means shall be employed to eliminate any partial discharge or corona that may occur after a prolonged service period. For epoxy resin transformers, suitable fillers shall be mixed in the epoxy resin to provide high mechanical strength and resilience to shock.
Natural ventilation shall be used for attaining the rated output and air channels through winding spools to attain sufficient cooling shall not be accepted.

Internal electrical connections shall be brazed and/or fixed with bolts and nuts. Soldered or mechanically crimped joints shall not be accepted.

Core bolts where used shall be insulated from the respective magnetic circuits with material capable of withstanding a test voltage of 2000V r.m.s. for one minute.

**C7.10.5 Tap Changers**

The off-load tap changers shall be accessible through the transformer top cover plate by means of copper links. The transformer top cover plate shall be fitted with an electrical and mechanical interlock designed to prevent access to the transformer tapping links until the auto-transformer starter circuit breakers are open and the 'START' and 'RUN' circuit breakers are in the 'CIRCUIT EARTH' position.

**C7.10.6 Internal Earthing of Transformers**

Metal parts of the transformer with the exception of individual core laminations, core bolts and associated individual clamping plates shall be maintained at some fixed potential. Where metal parts of the core are connected to earth this shall be done by way of accessible links to allow the insulation between core and earth to be tested. This insulation shall be able to withstand a test voltage of 2000V r.m.s.

The magnetic circuit shall be earthed to the clamping structure at one point only through a removable link placed in an accessible position beneath an inspection opening in the tank cover. The connection to the link shall be on the same side of the core as the main earth connection.

Where coil clamping rings are of metal at earth potential, each ring shall be connected to the adjacent core clamping structure.

**C7.10.7 Enclosure**

(a) **General**

The enclosure shall be of rigid construction and shall not be damaged at short-circuit faults. Exterior corners and edges shall be rounded to give a smooth overall appearance. The design of the enclosure shall ensure adequate ventilation and air circulation without forced cooling or additional electric fans.

The enclosure shall be designed so as to allow the complete auto transformer in the tank and filled with oil, to be lifted by crane or jacks, transported by road, rail or water, skidding in any direction on plates or rails without over-straining any joints and without causing subsequent leakage of oil.
The tank or enclosure exterior shall be fitted with a M12 stud at the bottom of the unit suitable for termination of a copper earthing bar of 32 x 3 mm.

(b) **Enclosures for Epoxy Resin Cast Auto-transformers - Additional Requirements**

Unless otherwise specified, a rectangular splash-proof enclosure of degree of protection to BS 5490, IP 32 shall be provided covering the entire unit. The enclosure shall be sheet steel of 2 mm minimum thickness and suitably braced to form a rigid structure. The enclosure shall be bolted to the transformer frame and shall be easily removable when required. Access panels and openings shall be provided to facilitate routine inspection and maintenance, and changing of tap position without the need for dismantling the enclosure completely.

(c) **Enclosure (Tank) for Oil-filled Auto-transformers**

(i) **General**

A rectangular totally enclosed tank to IP 65 shall be supplied covering the entire unit.

Oil tank shall be fabricated from weldable structural steel to BS EN 10137, BS EN 10029 or products having equivalent functions or performance, with all welding to BS EN 1011-1 or equivalent. Fabricated under bases shall be provided with skids and detachable rollers. The exterior of the tank shall be of plain sheet steel without stiffeners. Tank stiffeners shall be continuously welded.

Wherever possible the transformer tank and its accessories shall be designed without pockets wherein gas may collect. All joints of the oil tank other than those which may have to be broken shall be welded. Caulking of defective welded joints will not be permitted. All joint faces shall be designed to prevent the ingress of water or leakage of oil with a minimum of gasket surface exposed to the action of oil or air.

Unless otherwise approved, oil resisting synthetic rubber gaskets shall not be used, except where the synthetic rubber is used as a bonding medium for cork or similar material.

(ii) **Pressure Relief Device**

Each tank shall be fitted with an approved pressure relief device designed to protect the tank from damage and control the explosion of oil under internal fault conditions. The device shall operate at a static pressure of less than the hydraulic test pressure for transformer tank
but not exceeding 70 kPa. Means shall be provided to prevent the ingress of moisture and dust.

Unless otherwise approved the relief device shall be mounted on the main tank and, if on the cover, shall be fitted with a skirt projecting 25 mm inside the tank to prevent gas accumulation. If a diaphragm is used, it shall be of approved design and material and situated above the maximum oil level.

(iii) Tank Cover

Each tank cover shall be of adequate strength, and shall not distort when lifted. Inspection openings shall be provided as necessary for changing tap position. Each inspection opening shall not be less than 450 mm by 360 mm and shall not weigh more than 25 kg. The tank cover shall be provided with lifting welded eyes. The bolt holds in all cover plates shall be provided with washers which will prevent the collection of moisture in the bolt hole.

The tank cover shall be fitted with pockets for a thermometer and for the bulbs of the winding or oil temperature indicators. Protection shall be provided where necessary for each capillary tube. The thermometer pocket shall be fitted with a captive screwed cap to prevent the ingress of water. The pockets shall be located in the position of maximum oil temperatures at full rated power and it shall be possible to remove the instrument bulbs without lowering the oil level in the tank.

(iv) Transformer Auxiliaries

Each transformer shall be fitted with:

- An oil level indicator of prismatic glass visible from ground level and indicating the oil levels over the range specified. The oil level indicator shall be marked to indicate the correct oil level with the oil at a temperature of 15°C, 50°C and 90°C.

- An oil seal silica gel breather or other approved type device complete with dehydrating agent, indicator and sight glass. Breathers shall be at least one size larger than the size that would be fitted in temperate climate and shall be mounted approximately 1000 mm above ground level.

(v) Transformer Oil

The transformer oil shall comply with IEC 60296. The first filling of transformer oil shall be supplied with the Contract. All oil that may be used for works processing
or testing shall be compatible with the oil to be used on site.

(vi) Valves and Flanges

All valves up to and including 100 mm shall be of gunmetal. Larger valves may be gunmetal or may have cast iron bodies with gunmetal fittings. They shall be of the full way type with internal screw and shall be opened by turning counter-clockwise when facing the handwheel. Butterfly type valves shall only be used for isolation of radiator.

Means shall be provided for padlocking the valve in the open and closed positions.

Every valve shall be provided with a mechanical indicator to show clearly the position of the valve.

All valves shall be provided with flanges having machined faces.

Each transformer shall be fitted with the following:

- One 50 mm filter valve at the top and one 50 mm combined filter and drain at the bottom of the tank mounted diagonally opposite to each other for connection to oil circulating equipment,

- A robust sampling device at the top and bottom of the main tank. The sampling devices shall not be fitted on the filter valves specified above,

- A drain valve for oil tank,

- Flanged type air release plugs as necessary.

All valves opening to atmosphere shall be fitted with blank flanges.

C7.10.8 Finishes

(a) Surface Preparation

Before untreated steelwork is painted it shall be thoroughly cleaned by an approved method such as grit blasting to ISO 8501 or chemical pickling and an approved anti-rusting priming coat applied. Treated steelwork shall be suitably cleaned and degreased.

(b) Painting - External Surfaces
Panel surfaces shall have not less than one primer coat, two stoved undercoats and two top stoved coats of paint. Undercoats shall be epoxy based and easily distinguishable in shade or colour from the priming and finishing coats. The two final coats shall have a total minimum dry film thickness of 0.075 mm with each coat separately stoved in an air-circulating oven. The final paint coating shall be of semi-matt finish and the colour shall be approved by the Architect.

Oil tanks and other accessories shall be coated with air-drying paints by cold airless spray to a minimum total dry film thickness of 0.127 mm.

Bright/gloss parts shall be protected with a coat of readily removable composition which shall be effective in preventing corrosion during transport and storage.

(c) Painting - Internal Surfaces

In oil tank, interior surfaces shall be painted in an identical manner to the external surface with air-drying oil and petrol-proof paint. The finishing colour of oil tank shall be red.

For epoxy resin transformer enclosures, the interior surfaces shall be finished in white with anti-condensation paint.

C7.10.9 Rating Plates and Diagrams

The following plates shall be fixed to the transformer enclosure or tank at 1700 mm average height above ground level: -

(a) A rating plate bearing the data specified in BS EN 60076 or IEC 60076 and the duty rating.

(b) A diagram plate showing the internal connections and in addition a plan view of the transformer giving the correct physical relationship of the terminals. The percentage tapping shall be indicated for each tap.

(c) For oil immersed transformers, a plate showing the location and function of all valves and air release cocks or plugs. This plate shall also warn operators to refer to the Maintenance instructions before applying vacuum treatment.

(d) Identification plates for the purpose of each removable inspection cover e.g. tap changer access etc.

The above plates shall be of stainless steel or brass.

External plates and labels shall be fixed by phosphor bronze, stainless steel or brass screws with 3 mm thick fibre washers at the front and back of the fixing holes. Tapping holes in transformer tank walls for fixing plates will not be accepted.
C7.10.10 Cable Boxes

The auto-transformer cable boxes complete with cable glands shall be suitable for the termination of high voltage power cables.

Cable boxes shall be air insulated and designed to suit the termination of high voltage cables.

Cable boxes shall be designed to accommodate all cable joint fittings or sealing-ends required by the manufacturers of the cables, including stress cones or other approved means for grading the voltage stress on the terminal insulation of cables.

Provision for earthing the body of each cable box shall be made.

Cable boxes designed for three-core cable shall have seating sockets on the two outer phases inclined towards the centre to minimise bending of the cable cores. Where there is more than one core of cable per phase, the socket block shall be so designed as to minimise bending of the cable cores.

C7.11 HIGH VOLTAGE - POWER FACTOR CORRECTION CAPACITORS

The power factor correction capacitors for the high voltage chiller motors shall improve the overall power factor of the chiller motors to 0.95 lagging at rated output power. The kVAr rating of the capacitor shall not exceed 85% of the no load magnetising kVAr of the chiller motor.

Specific requirements of the power factor correction capacitors shall be as follows:

- Type - Low loss dielectric type, indoor and enclosed in floor-mounted cubicles
- Rated Capacity - To suit the power factor to be improved
- System voltage - 3.3 kV, 6.6 kV or 11 kV as specified
- Frequency - 50 Hz
- Connection - Delta-connected single-phase units
- Insulation Level - 45 kV peak impulse voltage for 1/50 microseconds
- Protection - 3 line connected high voltage HBC fuses to BS 2692 with striker pin

The output ratings of the power factor correction capacitor may require modification subject to the no-load magnetising kVAr rating of the high voltage motors to be driven.
The power factor correction capacitors shall be provided with combined jacking and haulage lugs to facilitate positioning. The capacitors shall be externally finished where applicable in semi-gloss stoved enamel or cellulose.

The power factor correction capacitors shall be protected by high voltage high breaking capacity fuses with striker pins to BS EN 60282-1. The striker pin shall be arranged to operate an auxiliary contact to trip the starter circuit breakers.

The power factor correction capacitor cable box complete with cable glands shall be suitable for the termination of the high voltage power cables.

C7.12 HIGH VOLTAGE - POWER CABLES

C7.12.1 General

All 3.3 kV, 6.6 kV and 11 kV power cables shall be insulated with cross-linked polyethylene which shall comply with BS 6622 or IEC Standard 502-1, and where specified, cables shall be wire armoured and finished overall with a continuous outer sheathing of polyvinyl chloride (PVC).

All cables shall be designed for operation on a system earthed either direct or through resistance or reactance at one or more neutral points.

No straight through cable joints shall be installed without the approval of the Architect.

For identification the rating of the cable shall be impressed into the outer insulation at regular intervals.

C7.12.2 Cross-Linked Polyethylene (XLPE) Cables

High voltage cross-linked polyethylene insulated (XLPE) cables shall be of the 1900/3300 V grade for 3.3 kV power cables, 3800/6600 V grade for 6.6 kV power cables and 6350/11000 V grade for 11 kV power cables.

Multi-core cables shall comprise section-shaped circular stranded annealed copper conductors. The insulation shall consist of cross-linked polyethylene applied by extrusion, bedded in a minimum of two layers of suitable tape. Armouring, where specified, shall comprise a single layer of galvanised steel wires or aluminium strip and the cable shall be served with an extruded layer of PVC.

Single core cables shall comprise circular copper conductors and where armoured shall comprise non-magnetic aluminium wire or strip.

C7.12.3 Conductors

Copper conductors shall be stranded and shall consist of plain annealed copper. Before stranding, the conductors shall be approximately circular in section, smooth, uniform in quality, free from scale, inequalities,
spills, splits and other defects. There shall be no joints in the wire except those made in the base rod or wire before final drawing.

The term 'annealed' signifies that the wire before stranding is capable of at least 15 percent elongation without fracture, the test piece being not less than 150 mm and not more than 300 mm long.

The stranded conductor shall be clean and reasonably uniform in size and shape and its surface shall be free from sharp edges.

In the formation of shaped conductors containing less than 19 strands the same number of strands shall be used as for a circular conductor of equivalent area.

For conductors having 19 strands or more the number of strands shall be the same as in a circular conductor of equivalent area, subject to a maximum permissible variation of plus or minus one strand. All the strands in any given shaped conductor shall be of the same nominal size.

C7.12.4 Cable Terminations

Cables shall be terminated in approved non-ferrous mechanical glands which comply with BS 6121 complete with compression devices for securing the cable sheath. An armour clamp may be required for bonding to metal sheaths. Where the cables are installed in entirely dry situations, the gland shall be designed with a compressible gasket or packing for securing the inner sheath and means of anchoring the armour. For cables installed wholly or partly in outdoor or damp conditions compressible sealing and clamping features shall be provided for securing the inner and outer sheaths and also the armour; barriers shall be incorporated to prevent the ingress of moisture.
SECTION C8

NOISE AND VIBRATION CONTROL

C8.1 GENERAL

This section of the Specification intends to direct the Contractor to select the appropriate and sufficient noise and vibration control measures on the plant/equipment, the interconnected piping, ductwork and conduit so that when the installed plant/equipment are put into operation, the resulting noise and vibration levels at locations within the building and at the adjacent or nearby buildings shall not exceed the acceptable limits as promulgated by the latest statutory requirements of the Environmental Protection Department.

The Corrected Noise Level at potential Noise Sensitive Receiver in the adjacent or nearby building, if so identified in the Particular Specification and/or Drawings, shall not exceed the Acceptable Noise Level stipulated in the Technical Memorandum for the Assessment of Noise from Places other than Domestic Premises, Public Places or Construction Sites issued by the Environmental Protection Department when the plant/equipment installed by the Contractor are put into operation.

C8.2 EQUIPMENT BASES

C8.2.1 General

Floor mounted equipment shall be installed on 100 mm high concrete housekeeping pads provided by the Building Contractor covering the whole floor area requirements of the equipment bases plus a minimum of 150 mm further on each side or on inverted beams at the roof. Vibration isolators shall be mounted on this concrete pad or inverted beams.

C8.2.2 Welded Structural Steel Bases

Bases shall be constructed of adequate 'I' or channel steel members reinforced as required to prevent the bases from flexing at start-up and from misalignment of drive and driven units.

All perimeter members shall be of steel sections with a minimum depth equal to 1/10th of the longest dimension of the base but need not exceed 350 mm provided that the deflection and misalignment are kept within acceptable limits as determined by the equipment manufacturer.

Height saving brackets shall be employed in all mounting locations to provide a base clearance of 50 mm.

C8.2.3 Concrete Inertia Bases

Concrete inertia bases shall be formed within a structural steel beam or channel frame reinforced as required to prevent flexing, misalignment of
the drive and driven units or transferral of stresses into equipment. The base shall be completed with height saving brackets, concrete reinforcement and equipment bolting down provisions.

In general the thickness of concrete inertia bases shall be of a minimum of 1/12th of the longest dimension of the base but never be less than 150 mm. The base depth needs not exceed 300 mm unless specifically required.

As an indication of the standards required, minimum thickness of the inertia base shall generally comply with the following table or be 1/12th of the longest dimension of the base, whichever is the larger: -

Table C.8.2.3 Minimum Thickness of Inertia Base

<table>
<thead>
<tr>
<th>Motor Size (kW)</th>
<th>Minimum Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.7 - 11</td>
<td>150 mm</td>
</tr>
<tr>
<td>15 - 37</td>
<td>200 mm</td>
</tr>
<tr>
<td>45 - 55</td>
<td>250 mm</td>
</tr>
<tr>
<td>75 - 185</td>
<td>300 mm</td>
</tr>
</tbody>
</table>

Base forms shall include minimum concrete reinforcement consisting of 13 mm bars or angles welded in place on 150 mm centres running both ways in a layer of 40 mm above the bottom, or additional steel as is required by the structural conditions.

Unless otherwise specified, concrete inertia bases shall weigh from 2 to 3 times the combined weight of the equipment/plant to be installed thereon.

Base forms shall be furnished with drilled steel members and with anchor-bolt sleeves welded below the holes where the anchor bolts fall in concrete locations.

Height saving brackets shall be provided in all mounting locations to maintain a base clearance of 50 mm.

C8.3 VIBRATION ISOLATORS

The following types of vibration isolation mountings or suspensions are not exhaustive but serve to cover the main types that shall be applied as appropriate unless otherwise stated in the Particular Specifications.

C8.3.1 Type 'A' - Free Standing Spring Mounts

These shall be free standing and laterally stable without any housing and complete with a minimum of 6.0 mm neoprene acoustical friction pads between the base plate and the support.

All mountings shall have levelling bolts that must be rigidly bolted to the equipment.
Spring diameters shall be no less than 80% of the compressed height of the spring at rated load with a horizontal spring stiffness 1.1 times the rated vertical spring stiffness.

Springs shall have a minimum additional travel to 'solid' (fully compressed) equal to 50% of the rated deflection.

Springs shall be so designed that the ends of the springs remain parallel.

The springs selected for any given application shall be non-resonant with the equipment's or support structure's natural frequencies. This shall apply to all springs hereafter described.

C8.3.2 Type 'B' - Restrained Spring Mounts

Equipment with operating weight different from the installed weight such as chillers, boilers etc. and equipment exposed to the wind such as cooling towers and other roof mounted plants shall be mounted on spring mountings as Type 'A' but a housing shall be used that includes vertical limit stops to prevent spring extension when some of the weight is removed, i.e. when the system is drained or lifted by abnormal wind pressure.

C8.3.3 Type 'C' - Double Deflection Neoprene Mounts

These mountings shall have a minimum static deflection of 8.5 mm. All metal surfaces shall be neoprene covered to avoid corrosion and shall have friction pads on both the top and the bottom so that they need not be bolted to the floor. Bolt holes shall be provided for applications where bolting down is required.

C8.3.4 Type 'D' - Neoprene Pads

These mountings shall consist of 'waffle' form neoprene pads of 8.0 mm thickness. Where required these shall be adhesive cemented to 3 mm steel plate of similar area so as to form a sandwich.

The area of pad to be used and the number of layers shall be determined for each application in accordance with the manufacturer's recommendations.

C8.3.5 Type 'E' - Spring Hangers

These shall contain a steel spring located in a neoprene cup manufactured with a grommet to prevent short circuiting of the hanger rod.

The cup shall contain a steel washer designed to properly distribute the load on the neoprene and prevent its extrusion.

Spring diameters and hanger box lower hole sizes shall be large enough to permit the hanger rod to swing through a 30° arc before contacting the edge of the hole and short circuiting the spring.
Springs shall have a minimum additional travel to solid equal to 50% of the rated deflection.

**C8.3.6 Type 'F' - Spring and Double Deflection Neoprene Hangers**

These shall be as Type 'E' but incorporate a 8 mm deflection neoprene element at the top of the hanger box.

The neoprene element shall be molded with a rod isolation bushing that passes through the upper part of the hanger box.

**C8.3.7 Type 'G' - Pre-Compressed Spring Hangers**

These shall be as Type 'F' but shall be pre-compressed to the rated deflection so as to keep the piping or equipment at a fixed elevation during installation.

The hangers shall be designed with a release mechanism to free the spring after the installation is completed and the hanger is subjected to its full load.

Deflection shall be clearly indicated by means of a scale.

**C8.3.8 Type 'H' - Spring Hangers (Ductwork Support)**

These shall be as Type 'E' but shall be provided with top and bottom eye bolts, the top one for bolting to the flat iron hanger strap and the bottom one for bolting to the flat iron ductwork strap.

**C8.3.9 Type 'I' - Double Deflection Neoprene Hangers**

These shall consist of a double deflection neoprene unit as Type 'C' which is mounted on the bottom of the hanger box.

The neoprene unit shall be molded with a rod isolation bushing that passes through the hanger box.

**C8.3.10 Type 'J' - All Directional Anchor Units**

These units shall consist of a telescopic arrangement of two sizes of steel tubing separated by a minimum 13 mm thickness of heavy duty neoprene isolation material for horizontal restraints.

Vertical restraints shall be provided by similar material arranged to prevent vertical travel in either direction.

**C8.3.11 Type 'K' - Pipe Anchors and Guides**

Resilient pipe anchor shall be formed by welding a steel pipe clamp to the pipe and the clamp in turn supported at its two ends by a pair of Type 'J' all directional anchor units. In this way, both the radial and axial motion of the pipe are controlled.
Resilient pipe guide shall be formed by welding localized longitudinal guide ribs around the pipe at location over which slides fit the oversized pipe clamp which is in turn supported at its two ends by a pair of Type 'J' all directional anchor units. In this way, radial motion of pipe is controlled while axial motion of pipe is guided.

C8.3.12 Type 'M' - Split Wall/Floor Seals

These shall consist of two bolted pipe halves with 19 mm or thicker neoprene sponge bonded to the inner faces.

Seals shall project a minimum of 25 mm past either face of the walls.

Where temperatures exceed 115ºC, fiberglass shall be used in lieu of the sponge.

C8.3.13 Type 'N' - Horizontal Thrust Restrainers

Air handling equipment shall be protected where necessary against excessive displacement which might result from high air thrusts in relation to the equipment weight.

The horizontal thrust restraint shall consist of a spring element located in a neoprene cup manufactured with a grommet to prevent short circuiting of the threaded rod. The thrust assembly shall be so designed that the spring element can be preseted for thrust at the factory and adjusted at the site to allow for a maximum of 6 mm movement at start and stop.

The assembly shall be furnished with one threaded rod and two angle brackets for attachment to both the equipment and ductwork or the equipment and the structure. Horizontal restraints shall be attached at the centre line of thrust and symmetrically on either side of the unit.

C8.3.14 Type 'O' - Built in Inertia Block Plant Support

Where specified in the Contract Document, the Contractor (or the Building Contractor) shall provide plant foundations and housekeeping pads in the form of large concrete blocks recessed into the main floor slab.

Unless otherwise indicated, the sides and bottom of the embedded portion of the concrete block shall be lined with a minimum of 50 mm thick 'load bearing' cork pad to the following specification.

Table C8.3.14 Density of Vibration Isolators

<table>
<thead>
<tr>
<th>Density Designation</th>
<th>Density (kg/m³)</th>
<th>Loading (kg/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light</td>
<td>3.0 – 4.5</td>
<td>250 - 2500</td>
</tr>
<tr>
<td>Medium</td>
<td>5.5 – 6.0</td>
<td>2500 - 20000</td>
</tr>
</tbody>
</table>
C8.4  PLANT/EQUIPMENT VIBRATION ISOLATION

C8.4.1 General

All vibration isolators shall have their known undeflected heights or calibration markings so that, after adjustment when carrying their loads, the deflection under load can be verified, thus determining that the load is within the proper range of the device and that correct degree of vibration isolation is being achieved according to the design.

The static deflection of the isolator at each support point shall not differ from the design objective for the equipment as a whole by more than ±10%.

The ratio of lateral to vertical stiffness for spring shall be not less than 0.9 nor greater than 1.5.

All neoprene mountings shall have hardness of 40 to 65 durometer, after minimum aging of 20 days or corresponding over-aging.

In order to resist corrosion, all vibration isolation mountings and hangers shall be treated as follows: -

(a) Springs to be neoprene coated or hot dip galvanized.

(b) Wearing hardware to be cadmium plated steel or stainless steel of an appropriate grade.

(a) All other metal parts to be hot dip galvanized.

For any Contract, all vibration isolators and associated equipment bases shall whenever possible be of the product of a single manufacturer. Acceptable manufacturer's systems shall strictly comply with the design intent of this and/or the Particular Specification.

C8.4.2 Selection Guide for Equipment Base and Vibration Isolator

Unless otherwise specified, the selection of the type of equipment base and vibration isolator (mounting/hanger) for different plant/equipment and on different floor spans and levels shall follow the requirements as indicated in the Selection Guide for Vibration Isolation (Table 42 of the latest edition of ASHRAE Applications Handbook) and the static deflection of the vibration isolator selected shall either provide a minimum isolation efficiency of 90% in ground floor areas and 95% in upper level areas or be not less than the corresponding values shown in Table 42. However, the Contractor shall be responsible to ensure that the selected vibration isolation system is suitable for the specific plant/equipment and the specific building structure on which the plant/equipment is mounted.
The Contractor shall provide more efficient isolation than those suggested in Table 42 in case if the adjacent occupied space is a noise critical area such as board room and executive office. Advice from vibration isolator manufacturer shall be sought if necessary.

**C8.5 PIPEWORK VIBRATION ISOLATION**

**C8.5.1 Flexible Connectors**

Flexible connector shall consist of a single or twin-sphere body manufactured with reinforced rubber, the ends of which are raised and wire reinforced to form the cuffs for sealing purposes. The cuffs shall be backed by floating steel flanges.

The rubber body shall be reinforced by multi-layered nylon tire cord fabric.

Flexible connectors shall have a life in excess of 10 years under the design working conditions.

The rubber membranes shall have an indelible identification system to clearly identify the model and hence suitability for the application and working conditions and have the date of manufacture moulded into the cover to ensure that no units that have exceeded the recommended shelf life are used.

Straight connectors shall be of the twin-sphere construction whilst elbow connectors shall be of the single-sphere construction.

Straight connectors connected to resiliently supported equipment shall be equipped with acoustical control cables to prevent excessive elongation of the connectors if the system operating pressure is in excess of the value recommended by the manufacturer for use without control cables.

Acoustical control cable assembly shall consist of four large triangle anchor plates, two control cables with large swedged-on end fittings and 13 mm thick acoustical washer bushings of sufficiently large load bearing area to isolate the end fittings, axially and laterally.

**C8.5.2 Flexible Metallic Hose**

Allowable stress levels should be within BS 5500 : 1985.

The corrugated seamless hose body shall be of the annular and close pitched type.

For all ferrous applications, the hose body and the braid shall be manufactured from stainless steel material to BS 1449 Part 2 Type 32lS31. End terminations shall be carbon steel threaded male nipples to BS 21 (BSP) for 65 mm size and below and flanges to BS 4504 NP Standard for 75 mm and above.
For copper or non-ferrous pipework systems, the hose body and the braid shall be manufactured in bronze throughout. End terminations shall be copper female ferules suitable for soldering.

The lengths of the flexible metallic hoses shall be in accordance with the manufacturer's recommendation.

C8.6 DUCTWORK VIBRATION ISOLATION

They shall be made of approved materials such as lead vinyl or similar of minimum surface density of 5 kg/m² and installed such that airflow is not obstructed. The material used shall be approved by the Fire Services Department.

C8.7 DUCTWORK ACOUSTIC INSULATION

Unless otherwise specified, the acoustic ductwork liner shall conform to the requirements of ASTM C 1071 Type II. It shall be composed of long textile-type glass fibres firmly bonded together with a thermosetting resin into a rigid board of 50 mm thickness and 48 kg/m³ density. The air stream surface shall be overlaid with a fire-resistant black acrylic coating which adds strength to the product during fabrication, installation and system operation. The manufacturer's product identification shall appear on the air stream surface.

All components of the acoustic insulation including coverings and adhesive shall have a fire hazard classification with a flame spread rating of not over 25, and a smoke developed rating of not over 50. Ratings shall be as established by the tests conducted in accordance with UL 723, ASTM E-84 or NFPA 255 or BS 476 Part 4. The Contractor shall certify in writing, before any insulation is installed, that the products to be used meet with the above criteria.

The acoustic linings shall have the following minimum sound absorption coefficients when tested in accordance with ASTM C-423.

Table C8.7 Minimum Sound Absorption Coefficient

<table>
<thead>
<tr>
<th>Octave Band Centre Freq. (Hz)</th>
<th>125</th>
<th>250</th>
<th>500</th>
<th>1k</th>
<th>2k</th>
<th>4k</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sound Absorption Coefficient</td>
<td>0.12</td>
<td>0.67</td>
<td>0.99</td>
<td>0.97</td>
<td>0.91</td>
<td>0.87</td>
</tr>
</tbody>
</table>

C8.8 ACOUSTIC DUCTLAG

Unless otherwise specified, the acoustic ductlag shall consist of 50 mm thick glass fiber/lead sheet or barium loaded vinyl sheet/glass fiber with a factory applied aluminium vapour-barrier jacket which shall also be used for thermal insulation of ductwork.
The fiber glass shall have a density of 24 kg/m³ and thermal conductivity of 0.032 W/m°C or lower. The lead sheet shall have a surface weight of 5 kg/m².

Ductlag shall have the following minimum sound transmission loss when tested in accordance with ASTM E-90.

Table C8.8 Minimum Sound Transmission Loss

<table>
<thead>
<tr>
<th>Octave Band Centre Freq. (Hz)</th>
<th>125</th>
<th>250</th>
<th>500</th>
<th>1k</th>
<th>2k</th>
<th>4k</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sound Transmission Loss (dB)</td>
<td>15</td>
<td>17</td>
<td>19</td>
<td>24</td>
<td>30</td>
<td>33</td>
</tr>
</tbody>
</table>

C8.9 DUCTWORK SILENCERS

Outer casing of rectangular ductwork silencers shall be fabricated from galvanized steel not thinner than 0.8 mm in accordance with the recommended practices in the ASHRAE Guide. Seams shall be 'lock-formed' and mastic filled. Each silencer shall be provided with flanged inlet and outlet. The internal baffles or splitters shall be of galvanized perforated steel not thinner than 0.5 mm and having a nominal open area of 30%.

All internal components shall be spot welded in place with welds on centres not exceeding 100 mm. All spot welds shall be treated after with anti-corrosive epoxy resin or other approved coating.

Manifolded silencers shall be provided with continuous metallic nosing crimped in place. Nosing pieces and tails shall be as per the manufacturer's design. The filler material shall be of inorganic mineral or glass fiber of a density sufficient to obtain the specified acoustic performance and be packed under not less than 5% compression to eliminate voids due to vibration and settling. Material shall be inert, vermin and moisture proof.

Combustion rating for the silencer acoustic in-fill shall not exceed the following when tested in accordance with ASTM E-84, NFPA Standard 255 or UL No. 723 or BS 476 Part 4.

- Flame Spread 25  
- Smoke Developed 15  
- Fuel Contributed 20

The silencer shall be leak-proof at a differential air pressure of 2 kPa.

Unless otherwise specified, ductwork silencers shall have the following minimum Dynamic Insertion Loss under forward and reverse flow conditions of 10 m/s: -
### Table C8.9 - (1) Insertion Loss (dB) - for Lowest Pressure Drop Silencer

<table>
<thead>
<tr>
<th>Silencer Length (mm)</th>
<th>Octave Band Centre Freq. (Hz)</th>
<th>125</th>
<th>250</th>
<th>500</th>
<th>1k</th>
<th>2k</th>
<th>4k</th>
</tr>
</thead>
<tbody>
<tr>
<td>900</td>
<td></td>
<td>5</td>
<td>9</td>
<td>14</td>
<td>23</td>
<td>24</td>
<td>14</td>
</tr>
<tr>
<td>1500</td>
<td></td>
<td>7</td>
<td>13</td>
<td>21</td>
<td>29</td>
<td>39</td>
<td>20</td>
</tr>
<tr>
<td>2100</td>
<td></td>
<td>13</td>
<td>18</td>
<td>28</td>
<td>40</td>
<td>47</td>
<td>26</td>
</tr>
</tbody>
</table>

### Table C8.9 - (2) Insertion Loss (dB) - for Low Pressure Drop Silencer

<table>
<thead>
<tr>
<th>Silencer Length (mm)</th>
<th>Octave Band Centre Freq. (Hz)</th>
<th>125</th>
<th>250</th>
<th>500</th>
<th>1k</th>
<th>2k</th>
<th>4k</th>
</tr>
</thead>
<tbody>
<tr>
<td>900</td>
<td></td>
<td>5</td>
<td>10</td>
<td>17</td>
<td>17</td>
<td>13</td>
<td>10</td>
</tr>
<tr>
<td>1500</td>
<td></td>
<td>8</td>
<td>15</td>
<td>28</td>
<td>30</td>
<td>21</td>
<td>14</td>
</tr>
<tr>
<td>2100</td>
<td></td>
<td>12</td>
<td>20</td>
<td>36</td>
<td>38</td>
<td>28</td>
<td>18</td>
</tr>
</tbody>
</table>

### Table C8.9 - (3) Insertion Loss (dB) - for Medium Pressure Drop Silencer

<table>
<thead>
<tr>
<th>Silencer Length (mm)</th>
<th>Octave Band Centre Freq. (Hz)</th>
<th>125</th>
<th>250</th>
<th>500</th>
<th>1k</th>
<th>2k</th>
<th>4k</th>
</tr>
</thead>
<tbody>
<tr>
<td>900</td>
<td></td>
<td>7</td>
<td>12</td>
<td>19</td>
<td>23</td>
<td>23</td>
<td>18</td>
</tr>
<tr>
<td>1500</td>
<td></td>
<td>10</td>
<td>18</td>
<td>30</td>
<td>42</td>
<td>34</td>
<td>23</td>
</tr>
<tr>
<td>2100</td>
<td></td>
<td>14</td>
<td>24</td>
<td>36</td>
<td>48</td>
<td>44</td>
<td>31</td>
</tr>
</tbody>
</table>

### Table C8.9 - (4) Insertion Loss (dB) - for Standard Pressure Drop Silencer

<table>
<thead>
<tr>
<th>Silencer Length (mm)</th>
<th>Octave Band Centre Freq. (Hz)</th>
<th>125</th>
<th>250</th>
<th>500</th>
<th>1k</th>
<th>2k</th>
<th>4k</th>
</tr>
</thead>
<tbody>
<tr>
<td>900</td>
<td></td>
<td>10</td>
<td>15</td>
<td>25</td>
<td>34</td>
<td>35</td>
<td>28</td>
</tr>
<tr>
<td>1500</td>
<td></td>
<td>16</td>
<td>22</td>
<td>38</td>
<td>45</td>
<td>46</td>
<td>41</td>
</tr>
<tr>
<td>2100</td>
<td></td>
<td>17</td>
<td>34</td>
<td>44</td>
<td>49</td>
<td>49</td>
<td>45</td>
</tr>
</tbody>
</table>

Unless otherwise specified, ductwork silencers shall have the following maximum self-generated sound power level (dB re $10^{-12}$ Watt) under the flow conditions of 10 m/s: -

### Table C8.9 - (5) Maximum Self-Generated Sound Power Level

<table>
<thead>
<tr>
<th>Silencer Length (mm)</th>
<th>Octave Band Centre Freq. (Hz)</th>
<th>125</th>
<th>250</th>
<th>500</th>
<th>1k</th>
<th>2k</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lowest</td>
<td></td>
<td>51</td>
<td>51</td>
<td>49</td>
<td>47</td>
<td>50</td>
</tr>
<tr>
<td>Low</td>
<td></td>
<td>52</td>
<td>46</td>
<td>43</td>
<td>42</td>
<td>45</td>
</tr>
<tr>
<td>Medium</td>
<td></td>
<td>54</td>
<td>52</td>
<td>50</td>
<td>47</td>
<td>48</td>
</tr>
<tr>
<td>Standard</td>
<td></td>
<td>69</td>
<td>63</td>
<td>64</td>
<td>61</td>
<td>63</td>
</tr>
</tbody>
</table>
Before ordering ductwork silencers the Contractor shall submit for the Architect's approval the proposed manufacturer's certified test data (from an approved laboratory) for pressure drop and insertion loss ratings.

C8.10 ACOUSTIC DOORS

Door leaf shall be at least 65 mm thick, fabricated from 1.5 mm steel and filled with sound-absorbing and damping materials. Door frame shall be fabricated from 1.5 mm steel and furnished in two inside and outside mitered and welded pieces.

Doors shall be fully gasketed, hinged and secured by approved latch mechanism.

Door hinges shall be of cam-lift type which shall raise or lower as the door is opened or closed respectively.

Side and head of door and frame shall receive two sets of self-aligning compression seals. Acoustic labyrinth shall be created when the door is in the closed position. Bottom of door leaf shall contain continuous compression seal and the gravity action of the cam hinges shall cause the door to compress the bottom seal tightly against the floor every time the door is closed.

Unless otherwise specified, the door shall be 1-hour fire rated and the compression seals shall be fire-resistant to BS 476 Part 20-22.

The acoustic door shall have the following minimum sound transmission loss when tested in accordance with ASTM E-90.

<table>
<thead>
<tr>
<th>Octave Band Centre Freq. (Hz)</th>
<th>125</th>
<th>250</th>
<th>500</th>
<th>1k</th>
<th>2k</th>
<th>4k</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sound Transmission Loss (dB)</td>
<td>26</td>
<td>42</td>
<td>43</td>
<td>47</td>
<td>52</td>
<td>56</td>
</tr>
</tbody>
</table>

C8.11 ACOUSTIC LOUVRES

Unless otherwise specified in the Particular Specifications, the acoustic louvres to be installed to the external walls of plant rooms when specified shall be not less than 300 mm thick.

Outer casings shall be made of 1.6 mm thick galvanized sheet steel. The noise absorbing surfaces of the louvre blades shall be made of 0.8 mm thick perforated galvanized sheet steel and all other surfaces of the louvre blades shall be made of 0.8 mm thick galvanized sheet steel.

Louvre blades shall be filled with glass fiber of density 48 kg/m$^3$.

The acoustic louvres shall have the following minimum Transmission Loss (TL).
Table C8.11 Minimum Transmission Loss (Louvre)

<table>
<thead>
<tr>
<th>Octave Band Centre Freq. (Hz)</th>
<th>125</th>
<th>250</th>
<th>500</th>
<th>1k</th>
<th>2k</th>
<th>4k</th>
<th>8k</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insertion Loss (dB)</td>
<td>7</td>
<td>11</td>
<td>12</td>
<td>13</td>
<td>14</td>
<td>12</td>
<td>9</td>
</tr>
</tbody>
</table>

Static pressure drop of louvres shall not exceed 50 Pa at a face velocity of 2.2 m/s.

C8.12 ACOUSTIC ENCLOSURES

C8.12.1 General

Where required for in the Contract Documents, double-wall, insulated, and air-pressure-tight acoustic enclosures for housing noisy plant or machinery shall be constructed as specified below and supplied by a specialist manufacturer of insulated housings and casings, with published standards of construction and performance.

C8.12.2 Panel Construction

The outer surface of the panel shall be made of 1.2 mm thick galvanized solid sheet steel and the inside surface shall be made of 0.8 mm thick perforated galvanized sheet steel. Interior panel perforation shall be of 2.4 mm round holes on 4.8 mm staggered centers.

Panels shall be 100 mm thick or as otherwise indicated and be filled with glass fiber insulation, 40 kg/m³ minimum density, with following UL Composite Fire Resistance Ratings or to BS 476 part 20-22:

- Flame Spread 15
- Smoke Developed 0
- Fuel Contributed 0

Mineral wool to a comparable specification would also be acceptable.

The insulation material shall be non-hygroscopic, inert and vermin-proof. It shall not settle, shed or dust.

Panel joints shall be of the joiner and connector type construction such that the adjacent panels are held rigidly in position, effective both on the inside and outside.

Mechanical joints shall be made leak-proof with ductwork sealer, which shall be retained between adjoining flat metal surfaces. Panel construction shall hold the assembly motionless to avoid sealer displacement. Sufficient sealer shall be used to allow extrusion of surplus sealer to give visible evidence of sealer. Assembled structure shall have deflection under load limited to 1/240 of span at 3.0 kPa pressure.
For spans greater than 3000 mm, additional and approved structural reinforcement shall be installed to provide for structural rigidity.

Connection of roof to wall panels shall be by suitably sized angles held by approved screws, and using an approved sealer to provide an airtight seal.

C8.12.3 Access Doors and Louvres

Where required for as shown in the Contract Documents, access doors and louvres forming part of the complete acoustic enclosures shall be of the acoustic type design.

Access door shall be 600 mm wide x 1,500 mm high or 900 mm wide x 1,800 mm high as specified in the Drawings or otherwise indicated. Each door shall be factory/workshop installed in its panel opening which shall be reinforced with 3.4 mm thick galvanized sheet steel channel of suitable width to suit the wall thickness of the panel. The doors shall be constructed of 1.2 mm thick galvanized solid sheet steel and they shall be 100 mm thick and of the overlapping seal type. Each door shall be equipped with single continuous air/acoustic seals around the sill, jambs and head and shall have 2 hinges and 2 latches with an inside release handle.

C8.12.4 Openings and Sealings

All openings with dimensions greater than 150 mm shall be factory/workshop cut and framed.

The clearance space between the acoustic enclosure and any ductwork, pipes, or conduits passing through the enclosure shall be tightly packed with glass fiber or rock wool. Both ends of the opening shall then be covered up by 1.2 mm thick sheet steel and sealed airtight by high pressure ductwork sealer.

C8.12.5 Acoustic Test Data for Panels

The minimum allowable Transmission Loss (TL) of the panel, including all components, when tested in accordance with ASTM E-90, shall be as stated below:

<table>
<thead>
<tr>
<th>Octave Band Centre Freq. (Hz)</th>
<th>125</th>
<th>250</th>
<th>500</th>
<th>1k</th>
<th>2k</th>
<th>4k</th>
<th>8k</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sound Transmission Loss (dB)</td>
<td>23</td>
<td>30</td>
<td>42</td>
<td>51</td>
<td>59</td>
<td>58</td>
<td>58</td>
</tr>
</tbody>
</table>
The composite panel assembly when tested in accordance with ASTM C-423, shall have minimum sound absorption coefficients as follows:

Table C8.12.5 - (2) Minimum Sound Absorption Coefficients

<table>
<thead>
<tr>
<th>Octave Band Centre Freq. (Hz)</th>
<th>125</th>
<th>250</th>
<th>500</th>
<th>1k</th>
<th>2k</th>
<th>4k</th>
<th>8k</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sound Absorption Coefficient</td>
<td>0.89</td>
<td>1.20</td>
<td>1.16</td>
<td>1.09</td>
<td>1.01</td>
<td>1.03</td>
<td>0.93</td>
</tr>
</tbody>
</table>

C8.13 PLANT ROOM ACOUSTIC LININGS

C8.13.1 Where required for as shown in the Contract Documents, the acoustic linings to walls or walls and ceilings of the plant rooms used to reduce the reverberant noise levels of the plant rooms shall comply with the following:

(a) The material and the sound absorption coefficients of the acoustic wall liner shall comply with Sub-section C8.7.

(b) The wall liner board shall be secured by 1.5 mm thick galvanized steel 'z' or channel sections of 50 mm deep which shall be firmly fixed to the wall surfaces at 600 mm intervals. The wall liner boards shall be protected by 0.8 mm thick galvanized perforated metal plates which shall be secured by self tapping screws to the galvanized steel sections. The perforated metal plates shall be removable to enable future maintenance.
SECTION C9

PIPE MATERIAL, VALVES, COCKS AND STRAINERS

C9.1 AUTOMATIC AIR VENTS

Automatic air vents shall be used where indicated. They shall have gunmetal or brass bodies, non-ferrous or stainless steel floats and guides, non-corrodible valves and seats. Each automatic air vent shall be controlled by a lock-shield valve. Air release pipes shall be run to discharge at the nearest suitable and visible point and agreed by the Architect.

C9.2 BALL FLOAT VALVES

Ball float valves shall be of the sizes indicated and shall suit the fill and expansion cisterns or tanks specified. Ball float valves for use with feed and expansion cisterns shall be of the long arm type arranged to shut off when the cistern contains 150 mm depth of water. Floats shall be of the vacated plastic or solid polystyrene construction and provided with a non-ferrous threaded in built connector.

C9.3 BUTTERFLY VALVES

C9.3.1 Butterfly valves shall be installed where indicated. These shall have resilient seats which are (in-the-field) replaceable with moulded-in O-rings to serve as a flange gasket. For sizes of 50 mm dia. to 150 mm dia. inclusive, a notched plate handle shall be provided for the control of the valve and indication of disk position. For sizes of 200 mm dia. and above, gear actuator shall be used. All butterfly valves shall be capable of bubble tight shut off. Butterfly valves shall comply with the recognised international standards.

C9.3.2 Grooved ends butterfly valves may also be accepted. The valves shall be in accordance with the following:

(a) Grooved ends butterfly valves shall be bubble tight closing to ISO 5208 standard, enabling quick assembly with mechanical grooved coupling on ISO standard pipes.

(b) The manufacturer shall provide independent laboratory tests such as Underwriters Laboratory or Factory Mutual Research for pressure rating. All testing records and data shall be submitted to the Architect for approval.

(c) Bodies shall be made of ductile iron grade 400-18, completely coated with polyamide or products having equivalent functions or performance against corrosion, suitable for the temperature range of 0°C to 50°C. The valve shall provide dead end service at maximum rating.
(d) The discs shall be made of ductile iron or brass ASTM B124, with EPDM coating for fresh water application.

(e) The shafts stems shall be made of ANSI 420 stainless steel.

(f) The control handles and the gear operators shall be suitable for locking in any position. The micro switches shall be built in the actuators and factory adjusted at full open and full closure. Manufacturer shall provide certificate of factory adjustment.

(g) Valve electric operators shall be mounted on valves and tested at factory.

(h) The valves shall have marking tag in accordance with ISO 5209 standard.

C9.4 CHECK VALVES

The body of the check valves shall be made of cast iron to BS EN1561 and ISO 185 while the flaps/discs shall be made of Bronze to ISO 197-4 or ductile cast iron. The discs of swing check valves shall be of light construction and pivot on a spindle secured by two phosphor-bronzed hangers. Each valve shall be fitted with a stop to prevent undue movement of the flap and shall be as silent as possible in operation.

The discs of lift check valves shall be provided with means of guiding the discs and preventing components from becoming detached in service.

Recoil check valves with size 100 mm and above should have removable cover on top of the outlet body casing to facilitate inspection of bearings and movement door.

C9.5 PIPEWORK APPLICATIONS

Except as may otherwise be specified in Particular Specification, the application of pipework types to the various systems shall be as stated in Table C9.5. All pipes and fittings shall comply with the relevant Standard and shall have suitable markings to indicate the Standard. All ferrous pipework shall comply with ISO 5730 and ISO R831.
Table C9.5 - (1) **Chilled Water and Low Pressure Hot Water Circulation (Closed System)**

<table>
<thead>
<tr>
<th>Size</th>
<th>Type</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>(i) Up to 125 mm</td>
<td>Steel to ISO 65 of appropriate grade</td>
<td>Black mild steel (painted external before insulation)</td>
</tr>
<tr>
<td>(ii) Over 125 mm up to and including 300 mm</td>
<td>Steel to ISO 2604-2, ISO 2604-3 and ISO 2604-6 with wall thickness not less than 6 mm</td>
<td>Black mild steel (painted external before insulation)</td>
</tr>
</tbody>
</table>

Note: For system sizes of over 300 mm these will be fully detailed in the Particular Specification.

Table C9.5 - (2) **Chilled Water Drain, Vent and Overflow**

<table>
<thead>
<tr>
<th>Size</th>
<th>Type</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>(i) Up to 125 mm</td>
<td>Steel to ISO 65 of appropriate grade</td>
<td>Galvanised</td>
</tr>
</tbody>
</table>

Table C9.5 - (3) **Chilled Water Condensate Drains**

<table>
<thead>
<tr>
<th>Size</th>
<th>Type</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>(i) Up to 125 mm</td>
<td>Steel to ISO 65 of appropriate grade</td>
<td>Galvanised</td>
</tr>
<tr>
<td>(ii) Over 125 mm up to and including 300 mm</td>
<td>UPVC to ISO 3127 and ISO 4422 or DIN 19532, 8061/8062</td>
<td>Self finish</td>
</tr>
</tbody>
</table>

Table C9.5 - (4) **Condenser Circulation Pipework, Fresh Water Closed System with Air/Water Heat Exchanger**

<table>
<thead>
<tr>
<th>Size</th>
<th>Type</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>(i) Up to 125 mm</td>
<td>Steel to ISO 65 of appropriate grade</td>
<td>Black mild steel (painted external before insulation)</td>
</tr>
<tr>
<td>(ii) Over 125 mm up to and including 300 mm</td>
<td>Steel to ISO 2604-2, ISO 2604-3 and ISO 2604-6 with wall thickness not less than 6 mm</td>
<td>Black mild steel (painted external before insulation)</td>
</tr>
</tbody>
</table>

Table C9.5 - (5) **Condenser Circulation Pipework, Fresh Water passing through Cooling Tower**
### Table C9.5 - (6) Condenser Circulation Pipework for Sea Water Treated Effluent Water and Brackish Well Water (Cooling tower or once through systems)

<table>
<thead>
<tr>
<th>Size</th>
<th>Type</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>(i) Up to 125 mm</td>
<td>Steel to ISO 65 of appropriate grade</td>
<td>Galvanised</td>
</tr>
<tr>
<td>(ii) Over 125 mm up to and including 300 mm</td>
<td>UPVC to ISO 3127 and ISO 4422 or DIN 19532, 8061/8062</td>
<td>Self finish</td>
</tr>
<tr>
<td>(iii) Over 125 mm up to and including 300 mm</td>
<td>Ductile iron to BS EN 545 of appropriate grade</td>
<td>Cold bitumen coated externally to BS 3416 internally lined with cement mortar as in Note 4 below</td>
</tr>
</tbody>
</table>

### Table C9.5 - (7) Cold Water Make-up Supply to Air Conditioning Plant Cold Feed

<table>
<thead>
<tr>
<th>Size</th>
<th>Type</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>(i) Up to 125 mm</td>
<td>UPVC to ISO 3127 and ISO 4422 or DIN 8061/8062</td>
<td>Self finish</td>
</tr>
<tr>
<td>(ii) Over 125 mm up to and including 300 mm</td>
<td>Ductile iron or uPVC as for fresh water at Table C9.5 - (5)</td>
<td>As ductile iron treatment as in Table C9.5- (5) (iii)</td>
</tr>
</tbody>
</table>

Where copper pipe work is indicated, the tubes shall be of the following types: -

(a) Light gauge copper to BS EN 1057.
(b) Where buried underground tubes shall be to BS EN 1057.
(c) Tubes shall be suitably joined by capillary or compression fittings to ISO 2016 or to ISO 6708 and ISO 7268. For jointing screwed copper tubes, cast copper alloy fittings to ISO 7-1 shall be used.

Note 1: - Expansion and contraction due to condenser water temperature changes must be adequately accommodated particularly for uPVC pipework.

Note 2: - uPVC pipe has several pressure ratings, i.e. appropriate grade for ISO 3127 and ISO 4422 and PN 4, 6, 10, 16, 25 bar at temperature of 20°C for DIN 19532, 8061/8062. If pressure ratings are not indicated in the
drawing or Particular Specification, Contractor shall provide pipes with pressure ratings equal to twice the actual working pressure to which the pipes are being subjected.

Note 3: Where uPVC pipe is likely to be exposed to sunlight, it shall be protected against the effects of ultra violet light by a suitable paint work coating material or other form of protection to be agreed with the Architect.

Note 4: All pipes and fittings shall be cement mortar lined in accordance with BS EN 545, BS EN 598, BS EN969, Type A - Portland pulverised fuel ash cement (PFAC) in accordance with BS 6588 with a minimum pulverised fuel ash content of 25%; or Type B - sulphate resisting cement (SRC) in accordance with BS 4027.

C9.6 PLUG COCKS

Plugs for gland cocks shall be ground in. A loose key of mild steel forged to shape shall be provided for each gland cock.

Air cocks shall be nickel or chrome plated, of the spoutless pattern and with screwed taper thread. Two loose keys shall be provided for each installation having up to ten air cocks and one loose key shall be provided for every additional ten air cocks.

Three-way cocks shall be of the 'T' ported type, the position of the ports being clearly grooved on the square end of the plug. A loose key shall be provided for each three-way cock.

C9.7 PRESSURE REDUCING VALVES

Where indicated pressure reducing valves shall be installed. Unless otherwise specified they shall be as follows: Valves of up to 50 mm size shall have bronze or malleable iron bodies and may have taper screwed ends. Valves of 65 mm size and over shall have cast iron bodies with ends flanged. Flanges for bronze and iron valves shall be to ISO 7005, each according to the maximum working pressure. Valves shall be of the following types, as indicated: -

(a) Valves for reducing pressure to apparatus not designed to withstand the maximum pressure of a high-pressure line shall be of an approved spring-loaded relay operated type. The valve seats and discs shall be of nickel-alloy or stainless steel and shall be renewable. Each valve shall be capable of maintaining a reduced outlet gauge pressure within 3.5 kPa of the set pressure and shall be installed with an excess pressure isolating protection valve on the low pressure side.

(b) Where the apparatus on the low-pressure side is capable of withstanding the maximum pressure of the high-pressure line, valves shall be of the single-seated spring-loaded diaphragm type. They shall be adjustable within the specified low-pressure range and shall be installed with a safety or relief valve on the low pressure side.
Each reducing valve shall be installed with an isolating valve and strainer on the high-pressure side, excess pressure isolating valve or relief valve on the low pressure side, pressure gauge with mild steel siphon and bronze cock followed by down-stream side isolating valve.

Unions shall be provided on the pressure reducing valve side of both isolation valves in order to facilitate removal of the pressure reducing valve set for servicing or replacement. Where indicated, a bypass valve shall also be installed.

C9.8  STRAINERS

Strainers shall be of the single or the double type as indicated with connections screwed thread for bores of up to and including 50 mm and flanged for bores of 65 mm and over.

Strainers of up to 50 mm shall be of gunmetal or bronze. The bodies of single strainers of 65 mm bore and above and all double strainers shall be of cast iron.

Straining cages and their supporting structure shall be of non-ferrous metal or stainless steel with 1.5 mm diameter perforations or finer if indicated. Cage shall be at least five times the cross-sectional area of the pipe.

Double strainers shall incorporate a changeover device to enable either strainer to be selected and to isolate the idle strainer from the fluid flow.

C9.9  SPECIALISED CONTROL VALVES

Motorised control valves, and solenoid valves used for automatic control purposes shall be as specified in Sub-section C5.49 or as indicated in the Particular Specification. Mixing valves shall comply with BS 1415 Part 2.

C9.10  VALVE APPLICATIONS

C9.10.1 For fresh and chilled water; gate valves shall be used except where regulation is required in which case globe valve shall be installed but they must be positioned so as not to prevent drainage of the piping.

C9.10.2 For fresh water service valve both the gate and globe type shall be constructed of cast iron body with bolted cast iron bonnet, malleable iron hand wheel, bronze wedge and seat, forged manganese bronze or high tensile bronze spindle, with graphited packing and compressed fibre.

C9.10.3 Sea water services valves installed in the sea water pump house and/or inside the air conditioning plant room shall be constructed of cast iron body with zinc free bronze trim, bolted cast iron bonnet, malleable iron hand wheel, zinc free bronze stuffing box, gland, thrust, plate, yoke, wedge, seat and yoke sleeve with nickel alloy faces, stainless steel spindle with outside screw of rising stem or inside screw of non rising stem (whichever is specified), gunmetal nuts, and graphited packing compressed fibre packing.
C9.11 VALVES AND COCKS

C9.11.1 Valves, cocks, taps and other accessories shall be of the type and working pressure suitable for the applied system and shall be supported by valid documents with approval from the appropriate authority. They shall also bear the appropriate ISO Standard with marks. See also Subsection B9.5 and B9.10.

C9.11.2 Bodies of valves and cocks of up to and including 50 mm size shall be of cast gunmetal or bronze; approved valves having hot-pressed bodies may be offered as an alternative.

C9.11.3 Unless otherwise specified, bodies of valves of 65 mm size and larger shall be of cast iron. Castings and pressings shall be of good quality, clean and smooth and free from scale or flaws.

C9.11.4 All working parts shall be of gunmetal or chrome nickel alloy. Holes in covers or in gates for screwed portions of spindles shall have full threads of a length not less than the diameter of the spindle over the threads. Glands shall be machined to provide a naming fit between the spindle and the stuffing box. Stuffing boxes shall be properly packed, or fitted with 'O' rings which shall be located in plastic bushes.

C9.11.5 Gate valves shall have split or solid wedge gates. Disc valves shall have renewable discs free to rotate on the spindle.

C9.11.6 Valves and cocks on mild steel pipework of up to and including 50 mm size shall have taper screwed ends, and of 65 mm size and above shall have flanged ends.

Valves and cocks on copper pipework shall have connecting generally as for fittings.

C9.11.7 Wheel valves where exposed to view on appliances such as fan coil units and induction units shall have union ends and either:

(a) Composition hand-wheels shaped to enclose the stem and gland, or,

(b) Easy clean polished lock shields and composition hand-wheels.

Valves not normally exposed to view shall be fitted with cast metal hand wheel or lock shields.

C9.11.8 Straight pattern valves shall be of the full-way gate type. Angle valves shall have domed discs designed to offer minimum resistance to flow.

C9.11.9 Regulating valves on circuits shall have characterised plugs and a lockable spindle with an indicator to show the proportional opening.

C9.11.10 Lock-shield valves shall have easy-clean shields or enclosures to match with the inlet valves; a minimum of two loose keys shall be provided for
each size of valve spindle used on the Contract. Where indicated, the lock-shield valves shall have characterised plugs as for the regulating valves.

C9.11.11 Isolating valves, lockable where indicated, shall be of the following types:

(a) Fullway gate type except for valves with side pressure tapping of up to 50 mm size which shall be of the oblique type;

(b) Parallel or taper plug type.

C9.11.12 Fullyway gate valves shall have metal wheel handles. Wedge gates and all seating, including the top of the wedge and the associated back seat of the bonnet facing, shall be accurately machined, or alternatively designed to provide a back seating. Plug valves shall be arranged for 90° operation with stops on the valve body to limit movement. Lubricated plug valves shall incorporate a check device in the plug for the retention of lubricant applied under pressure. A spare charge of lubricant shall be provided for each valve.
C10.1 GENERAL

The content related to electrical control shall be read in conjunction with Sections C4, C5 and C7.

The system monitoring instrument in this Section shall also meet with the requirements as stipulated in the latest Guidance Notes for Management of IAQ in Offices & Public Places and the Guide for Participation in the IAQ Certification Scheme published by the HKSAR Government.

Scale ranges shall be appropriate for indicating the extreme values, on and off state, of the plant. The design maximum operating condition shall be indicated at not less than 75% of the total scale length.

Where required in the Particular Specification, all signals generated from the instruments and devices shall be suitable to work in conjunction with a Central Control and Monitoring System (CCMS).

C10.2 SYSTEM STATIC PRESSURE GAUGES FOR AIR DISTRIBUTION SYSTEMS

System static pressure gauges shall be of the single limb inclined manometer type with an accuracy of ±3%.

C10.3 THERMOMETERS - AIR IMMERSION

Thermometers shall be of the mercury-in-glass type of at least 150 mm long with accuracy of ±0.5ºC.

C10.4 THERMOMETERS - LIQUID IMMERSION

Thermometers shall be of the mercury-in-glass type of at least 150 mm long with accuracy of ±0.5ºC.

Unless otherwise specified, material of thermometer pocket shall be of stainless steel grade 316.

C10.5 PRESSURE GAUGES FOR WATER SYSTEMS

Pressure gauges shall comply with BS EN 837-1 calibrated in kPa from zero to not less than 1.3 times and not more than twice the operating pressure of the respective equipment/system and shall be accurate to 1.5% of full scale reading, unless otherwise specified.
The dials of gauges shall not be less than 100 mm diameter and the cases shall be of polished brass or chromium-plated mild steel with optical sight glass.

Pressure gauges used solely to indicate the head and pressure of water shall be provided with an adjustable red pointer set to indicate the normal working pressure or head of the system.

C10.6 PITOT STATIC TUBE

The flow sensing device shall be of the annubar type in compliance with ISO 3966 and ISO 7194, inserted through the wall of the pipe via suitable bush supplied by the sensing device's manufacturer.

The equipment shall be manufactured by a reputable and proven manufacturer and shall receive the Architect’s approval before installation.

Each pitot static sensor shall be permanently marked externally with the direction of flow.

C10.7 ORIFICE PLATE METERING

Where these are to be installed the orifice plates shall be of stainless steel and of the well established manufacturer’s make with proven performance characteristics in compliance with ISO 5167-1. The resistance across the plant orifice shall not exceed 5 kPa (0.05 bar).

The plate shall have two valved tappings for connection to manometer or responder meter, etc., similar to that described in Sub-section C10.6 above.

C10.8 ELECTROMAGNETIC AND ULTRASONIC FLOWMETERS

The flowmeter shall be of the direct reading type, i.e. in l/s, and shall be suitable for the chemical and physical properties of the fluids to be measured and suitable for both horizontal and vertical installations.

Each flowmeter shall consist of the flow sensor, an integral signal converter/transmitter and a digital display unit. The flow sensor shall be installed in the water pipework without obstructing the flow. The protection class of the sensor and converter/transmitter housing shall be at least to IP 67 and IP 65 respectively. The flowmeter shall have a constant accuracy to a maximum error of ± 0.5% of the actual flow for flow velocity of greater than or equal to 0.5 m/s. The installation of the flowmeter shall be as per the manufacturer’s recommendation with sufficient length of straight pipe run both at the upstream and downstream piping.

The flowmeter shall conform to BS EN 50081 and BS EN 50082 or similar international standards on Electro-magnetic Compatibility (EMC) compliance for industrial and commercial applications.
The calculator unit of an energy meter shall calculate and display digitally the water enthalpy consumption in kWh with an accuracy to a maximum error of ±1.5% throughout the range of measurement. The number of digits of accumulated enthalpy consumption display shall not be less than six. The housing protection for the microprocessor and calculator unit shall not be less than IP 54. The requirement for the temperature sensors and the flowmeter shall be as specified elsewhere in this General Specification.

Signal connection facilities to the CCMS shall be provided for displaying the energy consumption computed and the flow rate and temperature readings.
C11 THERMAL INSULATION

C11.1 GENERAL

C11.1.1 Thermal insulation shall comply with the requirements of BS 5422 and BS 5970 or other statutory standards such as IEC, ISO and etc or equivalent.

C11.1.2 Unless otherwise indicated, all thermal insulating materials used within any building shall, when tested in accordance with BS 476 or equivalent comply with the following:

(a) BS 476 Part 12: Ignitable T;
(b) BS 476 Part 6: Fire propagation I < 12, i₁ < 6;
(c) BS 476 Part 7: Surface spread of Flame Class 1,

or comply with Sub-section C11.1.2 (a) as mentioned above and conform to Class 'O' to UK Building Regulation 1991 certified by the “Warrington Fire Test Laboratory” or approving organizations and standards recognised by the Fire Services Department.

C11.1.3 The insulation used for the air conditioning installation is “air” insulation which shall satisfy the following:

(a) Adequate strength and rigidity to maintain the thickness of air.

(b) Creating adequate number of closed air shells within the material to minimize heat loss due to convection and conduction.

(c) Covered on exposed surface with good quality foil to stop heat loss from radiation.

C11.1.4 Insulation materials and their finishes shall be free from asbestos. Where any work is carried out on existing insulation material or finish which contains asbestos in any form the Contractor’s attention is drawn to the responsibilities under the provisions of the Asbestos Regulations current in the Hong Kong SAR at the time of the works. The Contractor shall also notify the Architect should the presence of asbestos be suspected.

C11.1.5 Insulation materials and finishes shall be inherently proved against rotting, mould and fungal growth and attack by vermin, be non-hygroscopic and in all respects be suitable for continuous use throughout the range of operating temperatures and for the environment indicated.

C11.1.6 The Contractor shall bear the cost and provide relevant certificates from an approved testing laboratory in order to prove the physical properties of the insulation to be used in the projects are conforming to the specification.
C11.2 TYPES OF THERMAL INSULATION MATERIALS

The type of insulation required for a particular installation will generally be indicated in the Particular Specification. Where this is not so the Contractor shall include for the types described herein:

C11.2.1 Type 'A' - CFC & HCFC Free Phenolic Foam Insulation

(a) Temperature range: sub zero to 120°C

(b) Density: 40 kg/m³

Except at pipe, ductwork and other support points where a higher density load bearing quality insulation shall be used in accordance with the manufacturers’ recommendations. In general, phenolic foam sections with 80 kg/m³ for pipe sizes of up to 125 mm and 120 kg/m³ for pipe sizes of 150 mm or above and made to the same thickness as the adjacent pipe insulation.

(c) Compressive strength: 140 kN/m²
   (BS 4370: Part 1, method 3 or ISO 844):

(d) Thermal conductivity: 0.022 W/m°C at 20°C mean temperature
   (BS 4370: Part 2, method 7).

(e) Closed cell content: 90% minimum (BS 4370: Part 2, method 10 or ISO 4590).

(f) Vapour transmission: 10 micron gram meter/Nh at 38°C 88% RH (BS 4370: Part 2, method 8 or ISO 1663).

(g) Fire rating: shall have class ‘O’ fire rating and test certificate from independent laboratory.

The above properties shall be tested independent of facings which shall be factory applied Class ‘O’ double sided reinforced foil vapour barrier for both condensation control and mechanical protection. The external side shall be of white antiglare coating and the internal side shall be of aluminium foil fully adhered to the phenolic foam. Facing with all service jacket on the outside is also acceptable. The surface emittance of the all service jacket shall be 0.7 or greater when tested with ASTM E-408. In addition, the performance of both vapour barriers and all service jacket shall comply with the requirement stipulated at Sub-section C11.4.2

The manufacturer shall provide evidence if required by the Architect, that the above properties of the material supplied remains constant or are stable enough throughout the working life.
C11.2.2 Type 'B' - Preformed Rigid Glass Fibre Insulation

Where specified the Contractor shall supply and install preformed fibre glass sections of the appropriate size to fit hot water pipework only and capable of accommodating the temperature range for the system without structural failure of the fibres or the bonding agency.

Preformed fibre glass sections shall have a density of not less than 64 kg/m³ and a minimum length of 0.9 m. Butt joint tape not less than 100 mm shall be used to ensure perfect sealing of the joints between sections.

The thermal conductivity (k value) of the fibreglass shall not be more than 0.033 W/m°C at a mean temperature of 20°C. The fiber diameter of the fibreglass shall be of 4 to 10 micron and fibre length 3 to 6 cm.

All fibreglass insulation shall be completely sealed at all joints. All holes, tears, punctures, etc. made in the vapour barrier shall be completely sealed with the same specified foil tape.

C11.2.3 Type ‘C’ - Flexible (Semi Rigid) Glass Fibre Blanket Type Insulation

This form of insulation shall not be used on pipework.

Insulation used for ductwork shall be semi rigid having a density of not less than 32 kg/m³ and thickness not less than 38 mm. The fiber diameter of the fibreglass shall be of 4 to 10 micron and fibre length shall be of 3 to 6 cm.

The thermal conductivity (k value) of the fibreglass shall not be more than 0.036 W/m°C at a mean temperature of 20°C. The thermal resistance (R value) shall be more than 1.08 m²°C/W.

C11.2.4 Type 'D' - Flexible Closed Cell Elastomeric Insulation.

Flexible closed Cell Elastomeric Insulation shall be CFC free, in continuous lengths, with factory applied talc coating on inner surface. Flexible Closed Cell Elastomeric Insulation shall comply with the following requirements:

(a) Thermal conductivity (at 20°C mean temperature) : ≤0.04 W/m°C
(b) Density : 65 kg/m³ ± 5%
(c) Water vapour permeability (without additional vapour barrier foil) : 0.28 micron gram meter/Nh
(d) Maximum operating temperature : > 80°C
(e) No putrefaction and mildew shall form on the insulation material. The water absorption properties of the insulation shall be of not more than 1.5% after 28 days.

(f) The material, including adhesives and all accessories shall have fire properties to Class 'O' comply with the requirements of the latest edition of Building Regulation in UK. The insulation material shall be a 'built-in' vapour barrier and achieve condensation control without any additional vapour barrier foil.

(g) Smoke Visibility (ISO 5659-2)
The mean specific optical density, Dm shall be less than 500 under all test conditions. The thickness of the test specimen shall be 25mm and the Dm shall be the maximum value of the specific optical density ($D_{s10}$) of the three tests computed at 10 minutes time interval.

(h) Smoke Toxicity
The results shall comply and in accordance with either of the following standards or equivalent:

- Naval Engineering Specification (NES) 713 (Issue 3) – Determination of the Toxicity Index of the Products of Combustion from Small Specimens of Material

C11.2.5 Type 'E' - Polystyrene Insulation

Only where specified or approved preformed or slab polystyrene may be used.

Polystyrene insulation shall be of the required thickness to meet with the thermal insulation values stated in Sub-section C11.5 - Tables 'X' and 'Y' or as stated in the Particular Specification.

The material shall be of the type which is defined as ‘non-self combustible’. In all cases in order to meet with the requirements of Sub-section C11.3.

C11.2.6 Type 'F' - Hydrous Calcium Silicate (HCS) and Rock Wool Pipe Insulation.

This material is more appropriate to the insulation of hot pipework and other hot metallic surfaces.

Where specified or approved this material shall be provided in the preformed sections having a top density of 200 kg/m$^3$ of chemically-
reacted calcium silicate combined with mineral fiber, with factory applied jacket.

**C11.2.7 Type ‘G’ - Magnesia Insulation**

Where specified or approved this material is appropriate to the insulation of hot pipework and other hot surface. It shall consist of 85% magnesia with 15% cement bonding agent applied wet to the hot surfaces allowed to dry out and when the appropriate thickness has been achieved smoothed off, covered with galvanised iron netting of 25 mm mesh and then further covered with 15 mm of cement plaster trowelled smooth and when dry painted to an approved colour as Sub-section B11.8.

**C11.2.8 Type ‘H’ – Free CFC, HCFC and HCF Polyurethane Foam Insulation**

(a) Temperature range : Sub zero to 80°C  
(b) Density : 48kg/m³  
(c) Compressive strength : 245kN/m² (BS 4370 : Part 1, method 3 or ISO 844)  
(d) Thermal Conductivity 0.024W/m°C at 20°C mean temperature  
(e) Close cell content – 95% minimum (BS 4370 : Part 2, method 10 or ISO 4590)

The insulation panel shall be laminated at factory with a minimum of 60-micron thick aluminium foils on both sides. The aluminium foil shall be embossed and coupled with a 2g/m² layer of polyester paint. The aluminium foil shall comply with the following requirement:

(a) Aluminium with pureness 98.8% (Aluminium Alloy 8079)  
(b) Thickness : 60µm  
(c) Tensile strength (DIN 50154) : > 60N/m²  
(d) Elongation (DIN 50154) : > 8%

The insulation panel together with the above-specified aluminium foils shall achieve condensation control without any additional vapour barrier foil as stated in Sub-section C11.4.

**C11.3 MEASURE TO PREVENT SMOKE NOXIOUS & TOXIC FUME PROPAGATION IN EVENT OF FIRE**

When requested by the Architect, evidence of fire classification, obtained from an approved testing laboratory, shall be provided by the Contractor in order to certify that materials comply with Sub-section C11.1.

In exceptional circumstances, where insulation materials have been permitted which do not strictly meet with the fire properties stated in Sub-section C11.1, the materials shall only be provided on the condition that:

(a) The sections are secured to the pipework or ductwork with non-flammable or toxic smoke producing adhesives.
(b) They are wrapped in 25 mm mesh, 1mm thick galvanised wire netting and covered in self setting cement of not less than 15mm thick trowelled smooth and if required (because they are exposed) painted in accordance with Section A8.

Such insulation shall similarly be sealed above the ductwork fitted tight and adjacent to the ceilings and beams or at the points near other obstructions.

Where total sealing by galvanised iron wire netting and 15 mm of cement plaster cannot be achieved then such forms of insulation will not be permitted.

Permission to use insulation materials that must be sealed with cement plaster in order to avoid generation of toxic fumes and smoke in the event of a fire will only be given in those circumstances where such application is considered safe by the Architect.

C11.4 VAPOUR BARRIERS

C11.4.1 Where thermal insulation is applied to the outside of piped and ductwork services, equipment and plant used to convey, store or generate fluids or gases at temperatures lower than the design ambient dew point temperature indicated, a water vapour barrier shall be provided unless the tender specification states otherwise. The vapour barrier where employed shall be applied such that it is continuous and gives protection to the whole surface of the insulation which it protects.

It shall not be pierced or otherwise damaged by supports or by the application of external cladding.

The insulation on continuous pipe and ductwork shall be sectionalised by vapour barriers to be applied at a maximum of 5 m intervals to isolate condensation problems caused by perforation of external barrier to the affected section.

C11.4.2 Aluminium foil vapour barriers used for insulation of all pipes and ductwork shall conform to the following requirements:

(a) Machine Direction Tensile Strength (ASTM D828) ≥ 12kN/m
(b) Cross Direction Tensile Strength (ASTM D828) ≥ 9kN/m
(c) Bursting Force (AS2001.2.19 : 1988) ≥ 120N or Bursting Strength ≥ 6 kg/cm² in accordance with ASTM D774
(d) Water Vapour Permeance (ASTM E96) ≤ 1.0ηg/Ns
(e) Surface emittance of external surface (ASTM E408) ≥ 0.7

C11.4.3 All joints shall be either factory or on job site fabricated. All joints shall allow for 50 mm overlap of vapour barrier and the joints shall be completely sealed using foil tape with a minimum width of 100 mm conforming to the following specifications:
(a) Tape thickness minimum 38 micron without release paper
(b) Machine and Cross Direction Tensile Strength (ASTM D882) ≥2.0kN/m
(c) Bursting Strength ≥ 10kg/cm in accordance with ASTM D3662
(d) Peel Adhesion to steel (ASTM D3330 : 1986) ≥ 10N/25 mm
(e) Shear adhesion (BS7116) : 311
(f) Surface Emittance (ASTM E408) ≥ 0.7

Any and all punctures, holes, tears, etc that can be seen or occur on the job site shall be completely sealed with the same tape as specified above.

C11.4.4 The material chosen for the vapour barrier and its method of application shall be compatible with the thermal insulation on which it is to protect. The following shall be used:

(a) Wet-applied vapour barriers of the cut-back bitumen type, bitumen emulsions with or without elastomer latex, vinyl emulsions and solvent based polymers.

(b) Elastomer sheets with all joints adequately overlapped and continuously sealed.

(c) Polyvinly chlorides, polyethylene, polyisobutylene or other plastics tapes or sheets.

(d) Epoxide and polyester resins.

(e) Sheet metal with all joints adequately overlapped and continuously sealed to a vapour-tight condition.

(f) Metal foil used alone or laminated to building paper, building sheet or plastics film with all joints adequately lapped and continuously vapour sealed.

Facing materials used on insulation materials to provide vapour barrier shall not be more than 0.8 mm thick. All metal foil vapour barrier and foil tape used shall be of Class 'O' to UK Building Regulation 1991.

C11.5 INSULATION THICKNESSES

Table C11.5 – (1) Minimum Thickness of Insulation (mm) for Chilled Water installation (chilled water taken as at 5°C)

<table>
<thead>
<tr>
<th>Nominal size of pipe (mm)</th>
<th>Internal Cond. up to 28°C 80% RH</th>
<th>External Cond. up to 35°C 95% RH</th>
<th>Internal Cond. up to 28°C 80% RH</th>
<th>External Cond. up to 35°C 95% RH</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>30</td>
<td>45</td>
<td>40</td>
<td>65</td>
</tr>
<tr>
<td>20</td>
<td>30</td>
<td>45</td>
<td>40</td>
<td>70</td>
</tr>
</tbody>
</table>
The above table assumes pipe to be steel to BS 1387. For copper tubes similar insulation thickness shall be applied to tubes of comparable O/D.

The above table assumes surface emittance of external surface (ASTM E408) \( \geq 0.7 \)

Table C11.5 – (2) Minimum Thickness of Insulation (mm) on Ductwork and/or Plant Equipment Carrying Warmed or Chilled Air.

<table>
<thead>
<tr>
<th>Maximum temperature diff. between internal ductwork air and external ambient air. % RH taken into account</th>
<th>Insulation thermal conductivity W/m°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>up to 0.024</td>
<td>0.025 to 0.04</td>
</tr>
</tbody>
</table>

15°C max. diff. for inside room air condition at approx. 65% RH

| 25 | 50 |

20°C max. diff. for external air condition at approx. 95% RH

| 60 | 100 |

Insulation thickness of minimum 25 mm shall be used for all condensate drain pipe.
SECTION C12
UNITARY AIR-CONDITIONER

C12.1 GENERAL

Unitary air-conditioners shall include:-

(a) Single package unit,
(b) Packaged unit and remote condenser,
(c) Condensing unit and blower coils,
(d) Condensing unit with variable refrigerant volume control and indoor fan coil units,
(e) Multi-split system and
(f) Water-cooled package and water pump package

Unitary air-conditioners shall be factory fabricated and assembled. The equipment shall be rated and tested in the same country of manufacture and meet with the requirements of the American Air-conditioning and Refrigeration (ARI) Standards 210 or other international recognized quality assurance standards approved by the Architect.

The most energy efficient model in the series shall be selected for submission and shall be referred to Sub-section C12.20 of this General Specification.

C12.2 EQUIPMENT SUITABLE FOR LOCAL ELECTRICITY SUPPLY

Unless otherwise specified, electrical equipment of the unitary air-conditioners shall be suitable for use with 3-phase and neutral, 4-wire, 380/220 V ±6%, 50Hz. ±2% source neutral earthed system with provision of bonding.

Transformer may be used for equipment designed for operation on voltages other than those specified above. Whenever possible, these shall be installed within the unit.

C12.3 DE-RATING FACTOR APPLIED TO 60 HERTZ EQUIPMENT

In the absence of published manufacturer’s rating for 50 Hertz operation, a factor of 0.83 is to be applied to the capacity rating of unitary air-conditioners manufacturers for 60 Hertz operation subject to the approval by the Architect.

C12.4 SELECTION OF AIR-COOLED CONDENSERS AND CONDENSING UNITS

Air-cooled condensers and condensing units of unitary air-conditioners shall be selected to give rated capacity with condensing temperature not exceeding 50°C for the ambient condition as specified under Sub-section A3.1.10 of this General Specification.
C12.5 CASING

Casings of unitary air-conditioners shall be constructed of rigid galvanised sheet steel and painted in accordance with Section A8, suitably reinforced with channels and sections to form a robust cabinet. Casing for outdoor installation shall be of weatherproof finish, preferably galvanised, painted or anodized aluminum.

C12.6 COMPRESSOR

Compressors shall be rotary, scroll or reciprocating of either the hermetically sealed type or the semi hermetically sealed type. Compressor shall be complete with internal motor protection, positive lubrication, mufflers, crankcase heater, and internal and external vibration isolation.

C12.7 SUPPLY AIR FAN AND MOTOR

Supply air fans shall be of the double width, double inlet, centrifugal type of ample sized for operation against the specified static pressure. Fan motors shall be permanently lubricated and have adequate power so as to be non-overloading throughout the range of the fan characteristic. The motor shall be high efficiency motor.

C12.8 COOLING AND HEATING COILS

Cooling coils shall be of the direct expansion type and constructed with copper tubes and aluminum fins to give high heat transfer performance. The coils shall have sufficient number of rows of tubes to provide efficient dehumidification of the air in addition to its cooling.

Heating coil shall be constructed with copper tubes and aluminum fins to give high heat transfer performance.

C12.9 AIR FILTER

Air filters shall unless otherwise specified be of the washable panel type and of an average weight arrestence efficiency not less than 85% according to ASHARE 52-76. Higher filter efficiency shall be adopted to meet with the IAQ objective designed and the requirement shall be referred to Section C1.

C12.10 AIR COOLED CONDENSERS

Air-cooled condensers shall unless otherwise specified be suitable for outdoor installation with ample capacity to dispose of the rejected heat from the air conditioning system. Condenser coils shall be constructed with copper tube and aluminum fins. Special corrosion resistant treatment for the condenser coils and fins shall be considered for the equipment to be located on corrosive environment.
C12.11 ELECTRIC DUCTWORK HEATER

Electric ductwork heaters shall be provided for winter heating or re-heating and designed in accordance with Section C3.

C12.12 REFRIGERANT PIPING

External refrigerant piping when required shall include all necessary valves, fitting and insulation. All insulation shall be properly protected with mechanical means such as metallic cladding or cement plastering and painting. Size of the refrigerant pipe and fittings shall be in accordance with the recommended standards as stated in Sections B6 and C6.

C12.13 CONDENSATE DRAIN PIPE

Condensate drain pipe shall be adequate insulated and mechanical protected in accordance with Sections B11 and C11 of this General Specification.

C12.14 SAFETY CONTROL

Controls shall be factory wired. Field wiring in conduit or trunking shall be limited to interconnections between separate pieces of equipment and power wiring. Each unit shall be protected and controlled by a factory built control panel incorporating all necessary devices, switches, indicator, etc. Functions required shall include those such as interlock with lubricating oil pump and other auxiliary components for unit starting, control circuit for compressor stop with pump down and crankcase heaters, automatic unloading, isolating switches and emergency stop facilities.

Safety protections shall include low lubricating oil pressure cutout, low evaporating pressure cutout, high condensing pressure cutout, low refrigerant temperature cutout, high motor coil temperature cutout, and other protections necessary for the proper and safe operation of the unit. Overload and motor burnout protections shall be provided as well.

C12.15 OPERATIONAL CONTROL

For a conventional split type A/C unit, a wired or wireless remote controller shall be provided for the selection of room temperature setting, fan speed and timer setting. For an advance multi-zone modular split type, the remote controller shall be of the liquid crystal display (LCD) type with an on-off switch for operational features such as speed selection, timer setting, temperature setting, self-diagnosis function and auto restart function.

C12.16 SINGLE PACKAGED AIR-CONDITIONER

Single package unit shall be of the completely self-contained type with factory wired controls and factory assembled components and piping. The unit shall
include one/two rotary, scroll or reciprocating compressors of either the hermetically sealed or semi-hermetically sealed type, condenser coil, condenser fan and motor, direct expansion cooling coil, blower, air filters, drier of the renewable cartridge type complete with isolating valve, expansion valve, controls and safety devices all housed in a weather-proof and metal casing of robust yet attractive appearance.

C12.17 PACKAGED AIR-CONDITIONER WITH REMOTE CONDENSER

The unit shall contain all components factory assembled, (as the single packaged unit with the exception of the condenser), in a sturdy painted G.I. metal casing arranged for vertical or horizontal mounting inside the building.

C12.18 SPLIT CONDENSING UNIT AND AHU

The condensing unit shall include rotary, scroll or reciprocating compressors, air-cooled condensing coils, fans and motors control and safety devices, piping and all necessary accessories factory assembled in a weatherproof painted G.I. casing. The refrigerant circuit shall be field connected to the matched AHU or fan coil units each complete with direct expansion cooling coil, expansion valve, blower with motor and the necessary number of air filters in a well insulated, sturdy G.I. metal casing with paint to an attractive appearance.

C12.19 VARIABLE REFRIGERANT VOLUME SYSTEM

The air conditioning system shall be of the multi-zone modular split type. Each zone shall consist of one air-cooled outdoor condensing unit connected to a group of indoor fan coil units in one single refrigerant circuit. The outdoor unit shall not comprise more than three compressors. For multi compressors outdoor unit, one shall be inverter control compressor. The inverter compressor shall be incorporated with a frequency inverter control to achieve the optimum flow of refrigerant in response to the actual load.

The multi-zone modular split type unit shall be provided with heating (Heat Recovery) and cooling output simultaneously.

C12.20 ENERGY EFFICIENCY PERFORMANCE

All unitary air conditioners shall be selected aiming for the highest operation efficiency. The minimum Coefficient of Performance for Air-Cooled Unitary Air Conditioner excluding room cooler shall be as shown in the Table below:-

<table>
<thead>
<tr>
<th>Capacity Range (kW)</th>
<th>Above 10 and below 40</th>
<th>41 to 200</th>
<th>Above 200</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum Coefficient of Performance</td>
<td>2.2</td>
<td>2.2</td>
<td>2.4</td>
</tr>
<tr>
<td>(Cooling Mode)</td>
<td>Heating Mode</td>
<td>Heating Mode</td>
<td>Heating Mode</td>
</tr>
<tr>
<td>---------------</td>
<td>--------------</td>
<td>--------------</td>
<td>--------------</td>
</tr>
<tr>
<td>Minimum Coefficient of Performance (Heating Mode)</td>
<td>2.5</td>
<td>2.7</td>
<td>2.9</td>
</tr>
</tbody>
</table>
C13.1 FRESH WATER PUMPS

C13.1.1 Type

(a) Pumps for chilled water circulation or other fresh water pumping duties unless otherwise specified, shall be of one of the following types:

(i) Centrifugal type with volute casing split on the centreline of the shaft with suction and delivery connections flanged and fitted to the non-removable half of the casing, or

(ii) End suction type, the pump set shall be installed with spacer type coupling so that the pump impeller can be dismantled from the motor side for servicing without disruption of the pipe-work nor dismounting the motor, or

(iii) Vertical spindle type centrifugal pump with end suction at the bottom.

(b) Where large static heads have to be pumped against, type (a)(ii) or (a)(iii) shall be used in multi-stage configurations. Generally the type of pump required will be specified in the Particular Specifications and/or in the Tender Drawings. However, if this is not so, the type as detailed in (a)(ii) above shall be installed if suitable.

C13.1.2 Materials of Construction

Unless otherwise specified, the materials of construction of the pumps shall be as follows:

(a) Casing: Cast iron
(b) Impeller: Zinc free bronze (*cast iron or stainless steel)
(c) Shaft: Carbon steel (*stainless steel)
(d) Sleeves: Bronze (*stainless steel)
(e) Casing rings: Bronze (*stainless or cast iron)
(f) Shaft nuts: Bronze
(g) Stuffing box housing: Cast iron
(h) Glands: Carbon steel
(i) Lantern rings: Bronze

*Alternative materials subject to the approval of the Architect

Note 1: Stainless steel shall be used for water with temperature >28 °C.
C13.1.3 Standards

(a) Casing Material

Unless otherwise specified for the above types of pumps, cast iron shall comply with BS EN 1561 or ISO 185.

(b) Impellers & Guide Rings

The impeller shall be of the enclosed type and be of Leaded Gunmetal to BS 1400 or ISO 197-4, keyed to the shaft. Renewable guide rings shall be bronze and shall be provided in the casing, keyed to prevent rotation.

(c) Shaft, Sleeves and Glands

Stainless steel shall be to BS 970: Part 1 Grade 431S29, 304S15 or Grade 316S31, ground and polished.

Bronze sleeves shall comply with BS 1400 or ISO 197-4 and shall be provided through the sealing glands to protect the shaft from wear. The sleeves shall be keyed to prevent rotation and secured against axial movement.

(d) Stuffing Boxes and Drain Piping

Cast iron stuffing boxes housing shall comply with BS EN 1561 or ISO 185 and shall be of ample length with bronze lined gland and neck bush, fitted with approved packing and lantern ring water seal. Drain piping to the nearest builder's drain to remove gland leakage shall be provided. Alternatively, a mechanical seal may be offered. Mechanical seals shall be of leak free operation. The mechanical seal shall be the product of specialist proprietor and the materials used shall be suitable for the pumped liquid.

C13.2 SALINE WATER PUMP

C13.2.1 Type

(a) These pumps shall be utilized for pumping seawater, brackish well water, or treated effluent water wherever these applications apply.

(b) Unless otherwise specified, the configuration of saline water pumps inside a building plant rooms shall be of the split casing type as specified in Sub-section C13.1.1 (a)(i) while for installation in the primary harbour side sea water pump chamber, pumps shall generally be of the vertical spindle type as specified in Sub-section C13.1.1 (a)(iii).

C13.2.2 Materials of Construction
Unless otherwise specified, the materials of construction for saline water pump shall be as follows:

(a) Casing: Cast iron
(b) Impeller: Zinc free bronze (#see note 1)
(c) Shaft: Stainless steel
(d) Sleeves: Bronze (*stainless steel)
(e) Casing rings: Stainless steel
(f) Shaft nuts: Bronze
(g) Stuffing box housing: Cast iron
(h) Glands: Carbon steel
(i) Lantern rings: Bronze

*Alternative materials subject to the approval of the Architect
Note 1: Stainless steel shall be used for water with temperature >28 °C.

C13.2.3 Standards

(a) Casing

Unless otherwise indicated, the casing shall be of cast iron to BS EN 1561 or ISO 185 or better and approved.

(b) Impeller and Shaft Sleeve

Impeller and shaft sleeve of saline water pumps shall be of one of the materials as below:

(i) Zinc-free bronze to BS 1400 Grade PB1; or Grade CT1; or ISO 197-4;

(ii) Austenitic cast iron to BS 3468 Grade F1; or ISO 2892; or

(iii) Stainless steel to BS 970 Part 1, Grade 316S31.

(c) For pumping seawater in harbour area, items (b) (i) & (ii) above shall not be used.

(d) The shaft shall be of stainless steel to BS 970 Part 1 Grade 431S29 or Grade 316S31, ground and polished.

(e) Stuffing Boxes and Drain Piping

Stuffing boxes shall be of cast iron housing and ample length complete with bronze lined gland and necks bushes, fitted with approved packing and bronze lantern ring water seal. Drain piping to the nearest builder's drain for gland leakage shall be provided. Alternatively, a mechanical seal may be offered. Mechanical seals shall be of leak free operation. The mechanical seal shall be the product of specialist proprietor and the materials used shall be suitable for the pumped liquid.
C13.3 BOILER FEED PUMP

Unless otherwise specified, all feed pumps for boilers handling hot water at 175 degree C and above shall have the major parts, i.e. casing, impeller, shaft and wearing rings made of stainless steel to Grade 316.

C13.4 SUMP PUMP

C13.4.1 Materials of Construction of Dry Pit Pumps

Unless otherwise specified, the materials for dry pit non-clog pumps areas shall be as follows:

(a) Pump casing: Cast iron
(b) Impeller: Cast iron (*stainless steel)
(c) Shaft: Stainless steel
(d) Shaft sleeve: Stainless steel (*brass)
(f) Packing gland: Ductile iron (*brass)
(g) Casing bolts: Steel
(h) Cap screw and washer, impeller: Stainless steel
(i) Key, impeller: Steel

*Alternative materials subject to the approval of the Architect

C13.4.2 Materials of Construction of Submersible Pumps

Unless otherwise specified, the materials for submersible non-clog pumps shall be as follows:

(a) Pump casing: Cast iron
(b) Impeller: Cast iron (*stainless steel)
(c) Motor casing: Cast iron
(d) Shaft: Stainless steel
(f) Impeller screw: Stainless steel
(g) Mechanical seals: Carbon (*ceramic faces)
(h) Base plate: Steel
(i) Discharge elbow: Cast iron
(j) O-ring seal: Neoprene

*Alternative materials subject to the approval of the Architect

C13.4.3 General Requirements

All bolts nuts and fasteners shall be of stainless steel and electric cable entry shall be of watertight construction.

Sump pumps for rainwater application shall generally be of materials complying with Standards as specified in Sub-section C13.1.3. Sump pumps for pumping other fluids shall be of materials compatible with the fluid that are being handled. If sea water is pumped, the pump materials shall comply with Standards as specified in Sub-section C13.2.3. The sump pumps shall operate automatically by float level control.
The guide bars and brackets for wet sump installation shall be of stainless steel to Grade 316.

Cable supports shall be of stainless steel. A safety provision shall be incorporated for automatic electrical disconnection of the supply in case of cable entry seal failure.

Pumps for flammable zones shall be equipped with flameproof submersible motor in compliance with EN 50014(1977) and EN50018.

C13.5 BORE WELL PUMPS

All bolts, nuts and fasteners shall be of stainless steel and electric cable entry shall be of watertight construction.

Bore well pumps unless otherwise specified shall be of all stainless steel construction. The stainless steel shall be of Grade 304 for fresh water application while Grade 316 stainless steel shall be used for other water applications.

The level switch shall be of the maintenance free mercury type or electrode type.

C13.6 PUMP BASE-PLATE

The based plate shall be made of cast iron or fabricated mild steel. Couplings shall be flexible of the steel pin and synthetic rubber bushing type, and fitted with steel guards.

C13.7 VALVES

Automatic air valves, butterfly valves, check (non-return) valves and float ball valves, etc., shall be as specified in Section C9.

C13.8 VIBRATION ISOLATORS

The bases shall be mounted on the raised housekeeping plinth using appropriate anti vibration spring mountings that shall be individually selected according to load distribution and shall have an additional free travel equal to one half of the rated deflection as specified in Sub-section C8.3.

C13.9 GAUGES

Gauges shall be in accordance with Sub-section C10.5.
C13.10 DRAIN AND VENT

The drain vent shall be built in complete with a drain plug except where the pump is inherently self-venting, the drain and drip connection valves and air cock shall comply with Section C9.

C13.11 FLANGED CONNECTIONS

Pumps shall have flanged connections conforming to the Table of BS 4504 or ISO 7005 as appropriate to the maximum working pressure. Taper pieces shall be provided where necessary for connection to pipe-work.

C13.12 WATER FILTERS

The materials used in water filters shall not corrode or cause corrosion in the water and shall generally be as specified for water-cooled condensers and water chillers.

C13.13 SEA WATER STRAINER

The unit shall be completed with a motor-controlled continuously rotating inner drum and equipped with an automatic backwash arrangement.

The unit body shall be provided with an inspection opening for visual checking. In addition a drain opening with drain valve shall be provided at the lower part and connected to the nearest floor drain.

The straining element shall be of stainless steel Grade 316 and shall be of the type and size suitable for removal of materials as specified in the Contract Drawing/Particular Specification. A motor shall drive this inner drum with suitable geared facilities that shall be mounted on the top of the strainer body.

The body of the auto-strainer shall be of stainless steel grade 316 or if approved of cast iron to BS EN 1561 or ISO 185 or ASTM A436 Grade 1B or ASTM 278 Class 40 construction with BS970 Part 1 Grade 316 stainless steel liner, housing a rotating tapered drum attached to a stainless steel shaft of Grade 316. The unit shall be suitable in operation under a pressure of 1034 kPa at 65 °C.

The automatic control of backwash arrangement shall comprise a motor-controlled valve on the outlet and an adjustable timer and differential pressure switch set to a maximum pressure drop allowed to regulate the frequency of backwash. Such control shall form an integral part of the Central Control and Monitoring System (CCMS) if available.

The inner drum driving motor shall be drip proof squirrel cage motor.

C13.14 FEED AND EXPANSION FACILITY

C13.14.1 General
For the purpose of this General Specification, the following definitions shall apply:

(a) Cistern - An open top vessel  
(b) Water Tank - A closed vessel

C13.14.2 Types of Cistern and Tank

(a) Cisterns and tanks shall be of one of the following types as below:

(i) Welded or riveted mild steel, to BS 417: Part 2 Grade A, heavily galvanized after manufacture.  
(ii) Pressed steel sectional to BS 1564, heavily galvanized after manufacture.  
(iii) Fibre-glass or plastics, for cisterns not exceeding 500 litre capacity to BS 4213.

(b) Pressed steel tanks shall be of the externally flanged type and complete with all necessary tie rods. Galvanized mild steel cisterns and pressed steel tanks shall be cleaned and painted internally with two coats of an approved bituminous or epoxy solution or shall receive other such internal treatment as indicated.

(c) Covers to Cisterns

Each cistern shall be provided with a loose cover formed in sections not exceeding 2m long and 1m wide. Covers for plastic or fibre-glass cisterns shall be of the same material as the cistern body.

(d) Connections

Connections to mild steel cisterns and tanks shall be made by means of bossed, screwed flanges or pads and studs. Connections on mild steel cisterns shall be welded before galvanizing. Flanges shall comply with BS 4504 PN6 to PN40 as appropriate or ISO 7005.

C13.15 PLATE TYPE HEAT EXCHANGERS

The specification of plate type heat exchangers shall be in accordance with Sub-section C6.15 of this General Specification.