PROPOSED ADDITIONS AND ALTERATIONS WORKS FOR OFFICE OF FOOTBALL ASSOCIATION OF SINGAPORE @ 100 TYRWHITT ROAD, JALAN BESAR STADIUM, SINGAPORE 207542

TECHNICAL SPECIFICATION OF MECHANICAL & ELECTRICAL WORKS

3.0 AIR CONDITIONING AND MECHANICAL VENTILATION INSTALLATION

3.1 PIPING - GENERAL

a. General

All pipework, fittings and supports necessary for the proper functioning of the work, whether or not specifically shown on the drawings and/or called for in the Specification, shall be supplied and installed in full co-ordination with other services. The intent of this Clause is that, whereas all minor and incidental works are not necessarily shown and/or specified but are necessary for the completeness of the work, such items shall be provided within the Tender Price. Allowances shall be made in the Tender Price for all offsets and adjustments to pipe runs, etc. needed to overcome the obstructions of the building and other services despite the fact that they may not be shown in detail on the Drawings.

All pipe sizes shown in the Drawings are the nominal bore of the pipe.

In the case of internally lined pipe (e.g. cement, PVC, etc.) the pipe bore diameter shall be not less than the Nominal Bore (NB) diameter specified in the Drawings. Where necessary a larger pipe NB shall be provided and is deemed to be included without further clarification. No additional time or cost will be allowable to this subcontract for compliance with this requirement.

b. Cleanliness

All pipes and fittings shall be thoroughly clean before erection and be free of scale, burrs, obstructions and other deleterious matter and their coatings shall be completely intact.

c. Installation

All piping shall be machine or hacksaw cut. No flame cutting is permitted except with the express permission of the Engineer. All burrs on the inside of pipes shall be removed. Changes in direction shall not be made by bending pipes (except for 25mm diameter or smaller pipes) nor by fabricated bends. All piping shall be installed to avoid other services. Allowances shall be made for all minor adjustments to pipe runs etc., needed to overcome the obstructions of the building and other services, despite the fact that they may not be shown in detail on the Drawings.

d. Vents and Drains

Pipes shall be vented at high points with B.S.P. plugs and shall be provided with plugged drain connections at the low points.

e. Reducers

Eccentric reducers shall be used in all horizontal locations installed so that in liquid services the top is level and in gaseous service the bottom is level.

f. Welding and Brazing

All welding and brazing shall be done by welders appropriately qualified for the particular service in question, using welded materials of size and type recommended for the work involved. All residual scale, weld spatter and slag shall be removed from the piping.

The Engineer reserves the right to select up to 2 % of welds and request an appropriate destructive or non-destructive test to confirm the integrity of the weld. If there is any evidence suggesting that the welding/brazing is unsatisfactory, the testing sure scope shall be expanded and the Engineer may order any number of tests at no additional cost.

g. Provisions for Expansion

Piping shall be installed so that it is free to expand and contract without imposing undue stresses on any branch connection or piece of equipment.

h. Supports

Where supports are not detailed on the Drawings, ensure that the strengths and sizes of all pipe supports are adequate in all respects. Supports shall be arranged so that the piping loads are shared by the supports so that no fixing is over stressed. Pipe clamps, bands, saddles and the like shall be of 3mm minimum thickness.

Light gauge galvanized steel straps shall not be used. Where supports are not detailed on the Drawings, ensure that the strengths and sizes of all pipe supports are adequate in all respects. Supports shall be arranged so that the piping loads are shared by the supports so that no fixing is over-stressed. Pipe clamps, bands, saddles and the like shall be of 3mm minimum thickness.

Light gauge galvanized steel straps shall not be used.

i. Spacing

Spacing of supports horizontally and vertically shall not be greater than shown in the following table (all sizes in millimeters):

Spacing(mm)					
Pipe Size	UPVC	Stainless Steel, Copper	Steel	Cast Iron	Hanger Size
15	1200	1200	1200		10
20	1200	1800	1800		
25	1200	2100	2100		10
35	1200	2400	2400		10
40	1200	2700	2700		10
50	1200	3000	3000		10
65	1200	3300	3300	3000	12
80	2000	3600	3600	3000	12

Spacing(mm)					
Pipe Size	UPVC	Stainless Steel, Copper	Steel	Cast Iron	Hanger Size
100	2000	4100	4100	4000	16
150	2500	4100	4100	4000	20
200			4100	4000	2 x 20*
250			4100		2 x 20*
300			5500		2 x 20*
350			4100		2 x 20*
400			5500		2 x 20*
450			8000		2 x 20*
500			8000		2 x 20*
550			8000		2 x 20*
600			8000		2 x 20*

* One hanger each side

Pipe supports shall be located not more than 600mm from each change of direction, and additional hangers shall be provided to areas of concentrated loadings in the vicinity of valves and fittings.

Cast iron pipes and steel pipes with mechanical couplings shall have a minimum of two supports per length.

Engage a locally Registered Professional Engineer to endorse that the supports have sufficient strength to take the design weight of services and submit such endorsed calculations to the Engineer for review.

Any additional steel structure required for the support of the pipe is deemed to be included in the tender offered.

j. Attachment to Steel Structure

No welding to or drilling of structural steelwork is permitted. Holes may be drilled through the back of purlins to support pipes 50mm and smaller but other means must be used to support larger pipes.

3.2 PRE-INSULATED CHILLED WATER PIPING

Chilled water pipe shall be a factory pre-insulated system.

Chilled water pipe material shall be by the same manufacturer as that used for non-pre-insulated pipework and fully complying with clause on CHILLED WATER RETICULATION.

Insulation shall be machine injected polyurethane foam (containing no CFCs) of 48kg/m^3 density. The thermal conductivity shall not exceed 0.023W/mK at 10^0C and the compressive strength shall not be less than 260kPa. The minimum insulation

thickness shall be not less than that specified in the table for phenolic foam insulated pipe.The pipe jacket shall be spiral wound galvanised steel of minimum 0.6mm thickness.

The complete pre-insulated pipe system shall be deemed to have satisfied the local fire safety authority's requirements. Obtain all necessary test approvals to substantiate the above. Not withstanding any requirements from the local fire safety authority the complete pre-insulated pipe system shall be of Class 0 flame spread (to BS 476 Part 6 and 7) and capable of achieving 2 hours fire resistance (to BS 476 Part 8).

For field insulation around fittings, bends, valves and joints, provide skilled workers to carry out the insulation works using proprietary insulation kits.

3.3 CONDENSER WATER RETICULATION

Pipe

50mm diameter and smaller

BS 1387:1985 steel heavy grade galvanised. Jointing shall be by mechanical couplings with grooved pipe ends, mating flanges or screwed connections may be used. If flanged, galvanising shall be carried out after fabrication. No welding of galvanised pipework will be permitted.

65mm diameter and larger

Galvanised steel to BS 1387:1967 heavy grade or API 5L Standard. Jointing shall be by mechanical couplings with grooved pipe ends

Mating flanges may be used, however, if so, galvanising shall be carried out after fabrication. No welding of galvanised pipework will be permitted.

Fittings

50mm diameter and smaller

BS 143:1968 and BS 1256:1968 malleable iron, socketed or flanged. Union - malleable galvanised iron, iron to iron ground seats, screwed or flanged.

65mm diameter and larger

BS 143:1968 and BS 1256:1968 flanged, or grooved.

BS 1965 Pt 1:1963 heavy steel

General

Galvanising of pipe shall be in accordance with clause **PROTECTION AND SURFACE FINISHES**.

Galvanising shall be carried out post grooving or post welding.

Welds shall be properly wire brushed clean before galvanising, and pickling shall be carried out to remove mill scale and oils before treatment.

Vibration Isolation Requirements

1. Pipework on roof shall be vibration isolated using 50mm static deflection spring neoprene in series with two layers of neoprene pad separated by 2mm steel shims.

2. All main chiller plantroom pipework shall have minimum 38mm static deflection spring neoprene in series isolators.

3.4. CONDENSATE DRAIN

Pipework and Fittings

Copper pipe to BS 2871: Part 1:1971 (M) Table X with silver brazed joints and shall be minimum 25mm diameter for FCUs and 32mm diameter for AHUs.

Insulation

Insulation shall be as for **CHILLED WATER RETICULATION** except that thickness is 20mm. If chilled water is not used, then the situation may be as below for residential projects.

For residential projects, condensate pipe shall be insulated using vapour sealed closed cell elastomeric foam type insulation having a K factor not higher than 0.036 W/m/°C @ 0°C and an average water absorption of not more than 0.9% by volume over 28 days. Insulate all fittings in the pipework. All externally exposed insulation shall be aluminum clad for mechanical and UV light protection. The thickness of insulation shall be as follows for the various types of installation practices.

Description of Installation	Min. Thickness of Insulation Required
1. Concealed in brickwork with plaster	6mm (Insulation to be protected against deformation prior to plastering)
2. Running through air-con space, non air-con or general ceiling space	10mm
3. Running through bathroom ceiling space	13mm

Jointing of lengths of preformed insulation shall not be by means of adhesive tapes which deforms the insulation. Such joints shall be by proper gluing of mating faces of each length using glue and method recommended by the manufacturer. Insulation shall be protected against ultra violet light by means of encasing in PVC trunking when run in external to the building.

Insulation shall be fire and flame propagation tested to BS 476 Pt 7:1987 and exhibit Class 0 performance and BS 476 Pt 6:1989 and exhibit a Total Index of Performance of less than 12.

Insulation of Floor Trap

Insulate floor traps/drains to which condensate drainpipe discharges to, even though such floor traps/drains may be supplied/installed by others, in accordance with .2 above. Insulation shall extend all the way to the waste stack. Where exposed, insulation shall be jacketted with a metallic sheathing.

REFRIGERANT PIPEWORK

Pipe And Fittings

Copper to BS 2871:Part 2 1976 Table 2, Type C107 and Table 10.

Joints shall be silver brazed capillary type. All refrigerant pipework shall be run neatly inside PVC trunking when run within the ceiling space and outside to the compressor/condenser.

Vibration Isolation

Provide flexible connection on other means of vibration isolation as recommended by equipment manufacturer when connecting to vibrating equipment.

Insulation

All refrigerant suction lines shall be insulated using vapour sealed closed cell elastomeric foam type insulation having a K factor not higher than 0.038 W/m/°C @ 0°C, and an average water absorption of not more than 0.9% by volume over 28 days. Insulate all fittings in the pipework.

Insulation shall be fire and flame propagation tested to BS 476 Pt 7:1990 and exhibit Class O performance, and BS 476 Pt 6:1989 and exhibit a Total Index of Performance of less than 12.

Insulation thickness shall be in accordance with the following table depending on the installation practice:

Description of Installation	Minimum Thickness of Insulation Required
1. Concealed in brickwork with plaster	9mm (Insulation to be protected against deformation prior to plastering)
2. Running through aircon space	13mm
3. Running through non-aircon space	19mm
4. Running through bathroom ceiling space	25mm

Jointing of lengths of preformed insulation shall not be by means of adhesive tapes which deforms the insulation. Such joints shall be by proper gluing of mating faces of each length using glue and method recommended by the manufacturer.

Testing

Pressure test refrigerant system to 1.5 times working pressure with nitrogen for 2 hours. Systems shall be free of any leaks at test pressure.

3.5 VALVES, STRAINERS AND ACCESSORIES

Schedule I - Service and Valve Application

Service/Application	Chilled Water (6.7 to 12.2°C)	Condenser Water (30.5 - 36.0°C)
Isolation (IV)	A	B
Regulation Throttling (IR)	F	F
Non Return	K	K
Strainers	N	N
Drain	P	P
Vents*	P	P
Commissioning Valve Sets	CV3	-

- Refer to specification for further details.

Schedule II - Specification

Ref. from Sch. I	Valve Description	Size Range	British Standard
A	Bronze Full Way Gate Valve.	15 - 50mm	5154
	Butterfly Valve, Cast Iron Body, Stainless Steel Shaft, Resilient Seat, Stainless Steel Disk. Extended Neck, Threaded Lug Valve.	65mm and larger	5155
B	Bronze Full Way Valve	15 - 50mm	5154
	Butterfly Valve, Cast Iron Body, Resilient, Seat Stainless Steel Shaft and Disk. Threaded Lug Valve.	65mm and larger	5155
F	Bronze Oblique Double Regulating Valve	15 - 50mm	5154
	Cast Iron Flanged Double Regulating Valve	65 - 300mm	5152

For type A and type B valves, the following apply:

65mm to 150mm diameter inclusive : lever actuator with at least 10 discrete positions

: lockable

200mm to 300mm diameter inclusive : cast iron geared wheel with fully enclosed reduction gearing and position indication

350mm diameter and above : motorised actuator to be supplied by the valve manufacturer as an integral unit under this contract, sized to suit the opening/force closing

Ref. from Sch. I	Valve Description	Size Range	British Standard
K	Bronze Swing Pattern Non-Return Valve	15 - 50mm	5154
	Cast Iron Wafer Pattern Check Valves (Spring Loaded)	65 - 300mm	5155 (Long Pattern)
N	Bronze 'Y' Pattern Strainer	15 - 50mm	0.8mm perforations
	Cast Iron 'Y' Strainer	65mm and above	1.6mm perforations
P	Bronze Draw-Off Cock with Hose Union	15 - 25mm	2879
CV3	Bronze Commissioning Set comprising double regulating valve and metering station (2 test points)	15 - 50mm	5154
	Cast Iron Commissioning Set comprising double regulating valve and metering station (2 test points)	50 - 300mm	5152 (for double regulating globe valve)

Detailed Specification

3. All valves and fittings shall be manufactured under a quality system to BS 5750 and shall bear the BSI Kitemark to verify such quality standards.

4. In general, all threads shall be BS 21 tapered, flanges shall "raised face" type to BS 4504 (metric), all gland packing shall be asbestos free. Cast iron shall be grade 220, brass shall be CZ 114, unless otherwise noted.

5. The working pressure shall be at least 1050 kPa or 1.5 times the maximum system operating pressure, whichever is greater.

Chilled Water Service (6.7°C to 12.2°C)

6. Isolation (15mm - 50mm NB) - Type A

Item	Material
Threaded Connection	
Non Rising Stem	Gunmetal (BS 1400 LG2)
Screwed Bonnet	Brass (BS 2872 CZ122)
One Piece Wedge	Gunmetal (BS 1400 LG2)
Stem Ring	Brass (BS 2874 CZ121)
Body	Gunmetal (BS 1400 LG2)

7. Isolation (65mm NB and larger) - Type A

Item	Material
Butterfly Valve, Extended	
Neck, Resilient Seat	
Body	CI (BS 1452)
(lugged with raised face to BS 4504)	
Handwheel, Lever	CI (BS 1452)
Shaft	Stainless Steel 316
Disk	Stainless Steel 316
Seat	Bonded, Replaceable, EPDM

Bearings (3 nos. heavy duty) Self Lubricating

8. Regulation Duty (15mm NB - 50mm NB)

Item	Material
Type Rising Stem Screwed Bonnet Metal to Metal Seat Regulating Disc Double Regulating Device Threaded Connection	
Stem	DZR Metal (BS 2874)
Bonnet/Disk (f15 to f32)	DZR Metal (BS 2874)
Bonnet/Disk (f38 to f50)	Gunmetal (BS 1400)
Swivel Nut	DZR Metal (BS 2874)
Body	Gunmetal (BS 1400)

8. Regulation Duty (65mm NB and larger)

Item	Material
Type : Outside Screw and Rising Stem Copper Alloy Trim Flanged Connection	
Yoke Bush and Stem	Brass (BS 2874)
Stem	Brass (BS 2874)
Gland, Bonnet	CI (BS 2874)
Disk f50 to f125	Gunmetal (BS 1400)
Disk f150	CI (BS 1452)
Body	CI (BS 1452)
Body Seat Ring	Gunmetal (BS 1400)

7. Non-Return Duty (15mm NB - 50mm NB)

Item	Material
Type : Horizontal Swing Pattern Screwed Cover Metal to Metal Seat Horizontal or Vertical Mounting Screwed Connection	
Cap	Brass (BS 2874)
Hinge Pin	Brass (BS 2874)
Hinge	Brass/Gunmetal
Disk	Brass/Gunmetal
Disk Nut	Brass (BS 2874)
Body	Gunmetal (BS 1400)

8. Non-Return Duty (65mm NB and larger)

Item	Material
Type : Wafer Pattern Twin Disk Type H or V Mounting Flanges to fit BS 4505	
Body	CI (BS 1452)
Stop Pin, Shaft and Springs	Stainless Steel (BS 970 315S16)
Disks	Alum Bronze (BS 1400 AB2)
Seat and Seals	EPDM

9. Strainers (15mm NB - 50mm NB)

Type :
Bronze "Y" Strainer
Screwed Connection
Drilled and Tapped Bosses
for Differential Pressure
Measurement

Blow Down Valve Gland
Cock Provided
0.8mm Standard Mesh
Stainless Steel Strainer Media

10. Strainers (65mm NB and larger)

Type :
Cast Iron "Y" Type
Flanged Connection
Drilled and Tapped Bosses
for Differential Pressure
Measurement
Blow Down Valve Gland
Cock Provided
1.6mm f Holes in Stainless
Steel Mesh

11. Drains (20mm NB)

Item	Material
Type : Bronze Gland Cocks Square Head with Flow Indication Levers Supplied	
Gland	Gunmetal (BS 1400)
Plug, Body	Gunmetal (BS 1400)

12. Vent Cocks (5mm NB)

Vent cocks shall be bronze material with lockshield pattern and hose connection.

Condenser Water Service (30.5°C to 36.0°C)

As for Chilled Water except as follows:

1. Butterfly valves need not have extended necks.

2. Strainers shall have 2mm perforation stainless steel basket, except upstream of package unit condensers which shall be 1mm perforations.

3. In general, all valves and fittings shall be installed between mating flanges if greater than 50mm diameter. 50mm diameter and less may be threaded or grooved.

Valves and Fittings : General

1. Regulation Valves

   Regulation valves shall incorporate an integral water flow measuring capability.

   Such valves shall be calibrated and certified by an approved laboratory. Two sets of measuring kit shall be furnished for each type of valve, and handed to the Engineer at completion.

   Regulation valves shall be installed in accordance with the manufacturer's written instructions.

2. Balancing Valves

   Balancing valves shall be installed at all terminal units equipped with three-way control valves, multi-section coils, and other locations as indicated in the Drawings or required to balance the system. Balancing valves shall be installed in accordance with the manufacturer's written instructions. The valves shall be fully suitable for the rated test temperatures and pressures.

3. Constant Flow Valves

   Shall be factory set, pressure compensated, automatic flow controllers designed to limit the rate of flow to the required capacity within plus and minus 5% over an operating pressure differential of at least 14 times the minimum required for control.

   All internal parts shall be stainless steel, and valve shall be non-clogging.

   Certified performance data based on independent laboratory tests shall be submitted, and valve shall come complete with a metal identification tag chain, to show flow rate and differential pressure range.

4. Water Flow Measuring Devices

Pumps, chillers, etc. where indicated on the Drawings shall be provided with an annular flow measuring device, installed in accordance with the manufacturer's written instructions. The sensor shall be of 316 stainless steel. Furnish a measuring and readout meter kit for use with the annular sensors which shall be handed over to the Engineer at completion.

5. Flow Switches

Water flow switches shall be pipe-mounted, paddle type with adjustable sensitivity SPDT contacts. Contacts shall be rated for the voltage and current required for the application.

6. Test Plugs

Test plugs shall be the self-sealing type, suitable for measuring temperature and pressure. They shall be threaded into a welded socket and shall be appropriately rated for the application.

These test points shall be in addition to thermowells, pressure taps, and other sensor locations.

A commissioning kit containing temperature and pressure probes, readout meter, adaptors, hoses, etc., as required shall be handed to the Engineer at Completion.

7. Tundishes

Supply copper tundishes for all bleed off points in plantrooms. Condensate drains from all air handling units shall discharge separately into tundishes. Drain pipes from tundishes to wastes shall be included in this contract.

6. PRESSURE GAUGES

Pressure gauges shall have a 100mm diameter face, dual scale kPa and psi calibration. The range of gauges shall be such that the pointer is near two-thirds of the range under normal operating conditions. Provide gauge cocks for all gauges, and pulsation snubbers where necessary to provide a stable reading.

7. TEMPERATURE GAUGES

Temperature gauges shall have 100mm diameter flangeless faces, dual scale degree F and degree C calibration and a separate well of the same material as the pipe. The well shall be screwed into a socket of the same material as the pipe. The range shall be such that the pointer is in the middle third of the range under normal operating temperature.

8. FLEXIBLE PIPELINE CONNECTORS

Working pressure 1050 kPa or 1.5 times the maximum system operating pressure, whichever is greater.

Connectors shall be proprietary type with bellows of nylon reinforced synthetic rubber or stainless steel bellows as appropriate to the size and pressure duty.

Up to 50mm

Flanged or union end fittings

Larger than 50mm

Flanged ends with control bolts to limit elongation

9. FAN COIL UNITS

Each fan coil unit shall be of the ceiling mounted cassette type as shown on the drawings.

Each fan coil units shall be equipped with a self-diagnosis remote controller and having the features of setting of the room temperature (with digital indicator of room temperature), timer, air discharge direction (for cassette units), 3 fan speed selection, self diagnosis circuit with malfunction code display. The ceiling recessed type of fan coil units must be equipped with condensate drain pumps.

The unit shall have adequate external static pressure for connection to ductwork as shown on the drawings. Each ducted type of fan-coil units shall have ducting flanges for connecting flexible ducting.

8. Cross Fins Evaporator

The cross fin evaporator coil shall be constructed from strong clean copper tubes bonded to aluminium fins suitably spaced to ensure maximum heat transfer. The inlet of the coil shall be factory brazed to an electronic control valve. The face velocity of the coil shall be exceptionally low to ensure quiet operation.

The cross fin coil shall be of waffle louvre fins and inner grooved lining tube design to ensure highly efficient performance. Fin pitch shall not be less than 2.0mm.

9. Electronic Control Valve

An electronic expansion valves shall be factory brazed to the inlet of the coil. It shall adjust the refrigerant volume continuously in respond to load variations of the room by fuzzy logic control to maintain a precise constant temperature of +/- 0.5^0C.

10. Evaporator Fan

The evaporator fan shall be of the dual suction multi blade type with its length designed to match the coil width. The fan shall be statically and dynamically balanced to ensure low noise and vibration free operations. It shall be directly driven by a 3 speed induction motor. For ceiling ducted unit, the fan shall be able to cater for the static pressure of the system as shown in the drawing. The motor shall operate on 220V/1∅/50Hz.

11. Control

Computerised control shall be used to maintain a correct room temperature with minimum power consumption. Unit shall equipped with 3 speed fan controller, timer on/off control, temperature setting as well as actual room temperature display in LED indicators.

12. Network Control

A network controller will be connectable to operate and control all the fan coil units according to designed address of the fan coil units.

13. Air Filter

Long life type air filter shall be provided for each fan coil unit.

The air filter shall have a minimum effective life of 2500 hours.

10. Vibration and Noise Control

All fan coil units with capacity less than 2500 CMH may be suspended in the ceiling space with selected neoprene hangers. All units above 2500 CMH shall each be suspended with minimum 4 numbers spring-neoprene hangers.

All pipes connected to fan coil units shall be isolated with isolation rubber sleeves.

Discharge ducts (and return air ducts if any) shall be installed with flexible connectors similar to that of AHU. Noise leakage via the connectors must be insignificant, otherwise special lagging will be required.

For selected fan coil units the maximum allowable sound power level is specified in the equipment schedules. For all other fan coil units the sound power levels shall not exceed the following :-

Frequency Hz	SWL, dB re 10-12 Watts, at Octave Bands							
	63	125	250	500	1K	2K	4K	8K
NC 35	62	55	48	42	39	37	36	35
NC 40	66	59	53	47	43	42	41	40
NC 45	69	62	56	51	49	47	46	45
NC 50	73	66	61	56	54	52	51	50

All fan coil units with a sound power level greater than 65dBA located within a space of criteria NC 40 or less shall be supplied with specially constructed fan coil unit casings to prevent break out noise entering the space.

The subcontractor is to submit the manufacturer's sound power level data of fan coil units selected for review.

Where any doubt arises, the subcontractor shall arrange for at least two units of each model selected to be tested by a recognised testing authority to substantiate the manufacturer's sound power rating at the subcontractor's own expenses.

11. ELECTRONIC AIR CLEANERS (EAC)

Electronic air cleaners shall be installed in the return air duct of the airconditioning system for the spaces as shown on the drawings or defined as bars, discos or lounges. The EACs offered shall be Underwriter Laboratories Listed and/or Canadian Standards Association certified and approved for use in Singapore by the relevant authorities. The efficiency rating of the equipment shall be determined by ASHRAE Standard 52-76.

The EACs shall be designed for 240V, 50Hz operation with ground. The EAC shall be selected for airflow shown on the plans and sized for an efficiency of 95% for particles of 0.01 micron.

The EAC shall based on the principle of two (2) stage electrostatic precipitation; the first stage being the Ionizer section and the second stage being the Collector section. The EAC offered shall have a galvanised cabinet, permanently lubricated ball-bearing fan motor, heavy duty commercially med electronic cells, solid state power supply, protective screens/pre-filters etc.

The solid state power supply shall provide high voltage (DC) to the Ionizer section and to the Collector section. It shall be self-regulating without being affected by moderate fluctuations of the input voltage. It shall have a safety interlock switch which automatically interrupts power to prevent operation when the access door or grille is opened. The interlock switch shall be recessed to prevent accidental powering of the high voltage power supply, fan motor during normal maintenance. The EAC shall have a high voltage on the electronic cells. It shall have a status indication light to indicate proper power operation. All light indications and access door/grille shall be sited towards the front of the EAC or near side for easy access.

The Ionizer section and the Collector section shall be contained in the electronic cell. The Ionizer section and the Collector section of each electronic cell shall have at least nine (9) ionizing wires and seventy-two (72) collector plates respectively.

The air intake and discharge grille, the prefilter and the electronic cells shall be removable for cleaning without the use of tools. The electronic cells shall have a handle to prevent damage during handling. The power supply shall be capable of being removed from the unit without removing the electronic cells.

The duct mounted EAC shall be able to be monitored remotely by means of a Solid State Performance Indicator (SSPI) and shall have LEDs that display On/Off status, WASH and check indicator. The subcontractor shall provide voltage-free contacts at the ITB for the abovementioned points for BMS monitoring.

The On/Off operation shall be controlled by interlocking with the AHU operation. As air is paned through the EAC, bigger particles are to be trapped by the protective screen/ prefilters. The air is then cleared of the particles by the electronic cells.

When the deposit on the collector plates gets concentrated, an auto-wash indication light shall give early indication that servicing of the electronic cells is required.

11. GRILLES AND DIFFUSERS

General

Grilles and diffusers shall be of coloured anodised aluminium construction.

All grilles and diffuser shall be manufactured by a specialist duct fitting manufacturer.

Square Face Ceiling Diffusers

Square Face Ceiling diffusers shall be fixed blade type having horizontal air discharge, and shall be fitted with rear mounted opposed blade dampers, adjustable from the diffuser face.

Diffusers shall be arranged for flush mounting in lay-in type ceilings where face size is same as ceiling tile size, and overlap mounting in other ceilings. Face size of diffusers shall be 600mm square unless otherwise stated.

Slot Diffusers

Linear slot diffusers shall be suitable for recess mounting. Air delivery patterns for each slot shall be manually adjustable from diffuser face to give horizontal left or right or intermediate pattern. Each slot shall incorporate an air flow control device allowing the discharge rate to be varied from full flow to no flow. Control device shall be adjustable from diffuser face. Diffuser shall be complete with purpose made internally insulated plenum box to accept circular duct connection and end caps. Butterfly damper shall be provided in the circular connection.

Side-Wall Supply Grilles

Except where egg-crate type is specified, side-wall supply grilles shall be double deflection with vertical front bars, complete with opposed blade damper, and shall be arranged for overlap mounting. Damper shall be adjustable from the grille face.

Linear Grilles

Linear grilles shall be of all extruded aluminium construction. Bars to be horizontal, spacing approximately 12mm, thickness approximately 5mm.

Where grilles are only partially active the rear assemblies shall cover only the active sections, and the non-active sections shall be blanked off with matt black baffles.

Supply sections shall be fitted with rear assemblies consisting of opposed blade damper and vertical, individually adjustable air pattern control blade.

Return and Exhaust Grilles

Except where egg-crate is specified, return and exhaust grilles shall be non adjustable in direction and shall have longitudinal fixed blades, and opposed blade balancing dampers except as noted on the drawings. Damper shall be adjustable from the grille face. Grilles shall be arranged for overlap mounting.

External Fresh Air Intakes

Fresh air intakes shall be flush mounting with weather-proof horizontal fixed blades and shall be complete with aluminium or stainless steel birdscreen mesh. The free area shall be not less than 50% of the face area. Louvre profile shall be designed for high aerodynamic performance free from unnecessary obstructions to flow. Air flow and pressure loss data shall be submitted to the Engineer for approval prior to order placement.

Swivelling Long-Throw Air Jet Nozzle

The air jet nozzle shall consist of a long-throw cylindrical nozzle mounted in a multi-sectional hollow ball assembly. The cylindrical nozzle is mounted firmly inside the upper section of the ball. The lower half of the ball is further sectionalised, both parts being interconnected by a flange. The upper and lower half of the ball form an articulated joint so as to produce the swivelling action. This enables the cylindrical nozzle to be adjusted to a maximum of 30° of the outlet axis. The whole air jet assembly shall be constructed from aluminium.

Each air jet nozzle shall be capable of discharging air at a rate shown on the plans and achieve a minimum throwing range of 10m. The resulting Sound Power Level shall not exceed 30 dB(A).

Egg-Crate Grilles

Egg-crate grilles shall have coloured anodised aluminium cores in a regular grid pattern of approximately 12mm squares. Frames shall be designed for surface mounting with minimal projection.

12. SHEETMETAL DUCTWORK

General

All external ductwork, and all ductwork indicated on the drawings as sheetmetal shall be constructed of galvanised close annealed, patent flattened, cold rolled, mild steel sheets or continuous rolls, electrogalvanised, and in accordance with the requirements of the duct manuals of the Sheet Metal and Air Conditioning Contractors' National Association (Inc.). "HVAC DUCT CONSTRUCTION STANDARDS - Metal and Flexible 2nd edition 1995.

In the event of this Specification being a variance with any provision of the standard, the requirements of this Specification shall take precedence over the provisions of the manuals.

Material for ductwork 18 swg (1.2mm) and heavier shall be galvanised to 270 g/m² (Z27), while 20 swg and lighter shall be 220 g/m² (Z22).

Where aluminium is specified, it shall be to BS 1470 (N63) and aluminium sections to BS 1470 (HE 30 WP).

Ductwork shall be made up of full-sized sheets, and panels shall be cross-broken or ribbed, to prevent drumming. A high standard of construction is required for all ductwork, and particular attention shall be paid to the appearance of exposed ductwork.

The gauges of duct with appropriate flanging, intermediate reinforcement, support, accessories and finishing shall all be in accordance with the recommendations contained in the SMACNA standard mentioned above, except that no gauge thinner than 24g shall be used for any rigid ductwork irrespective of the size..

Flanging, intermediate reinforcement and support shall be all in accordance with SMACNA 1995. Where stainless steel material is substituted for galvanised sheetmetal, the gauge of material may reduce to the next lower available gauge, and shall be grade 316.

Sheetmetal ductwork shall be fabricated from continuous lengths of material, no lap to joints shall be permitted unless expressly approved by the Engineer, in which case additional reinforcement may be required at no additional cost.

All ductwork shall be machine bent to ensure neat and accurate alignment and construction. Longitudinal joints shall be extended to the flange back face. Sealant shall only be used between two sheetmetal surfaces, and shall not serve as the duct skin. Any ductwork poorly constructed will be rejected and ordered from the site.

Ductwork damaged prior to installation will also be rejected.

All short radius bends (where radius to centreline of duct is less than duct width) shall be fitted with 3 radiused splitters to reduce air turbulence and noise. All mitre bends shall be fitted with aerodynamic turning vanes.

Ductwork connecting to louvres grilles etc. shall be sealed using clamps, fixing screws and soft seals. Adaptors such as spigot flanges shall be provided to connect to louvres supplied by builder.

External Insulation (not exposed to weather)

All sheet metal air-conditioning ductwork unless shown on the drawings as internally insulated shall be externally insulated with fibreglass blanket of density 32 kg/cubic metre externally sealed with impervious vapour barrier of fireproof reinforced foil. Seal joints with 100mm wide self-adhesive foil vapour barrier tape.

Insulation thickness shall be 25mm or above in air conditioned spaces, and 50mm or above in non air conditioned spaces.

Insulation sagging shall be minimised by the use of straps for duct widths greater than 750mm. Strap spacing shall be maximum 800mm.

External Insulation (exposed to the weather)

Insulation shall be 50mm thick Polyurethane and wrapped with aluminium foil and chicken wire mesh after which 12mm thick cement plaster shall be applied over the surface. Paint with a weather resistant paint as in clause **PROTECTION AND FINISHES.**

Internal Insulation

Semi-rigid Rockwool mat faced blanket of density 60 kg/cubic metre and thickness as indicated on the drawings.

The lining shall be completely covered on the air stream side using uniformly perforated 0.7mm thick galvanised steel sheet providing no less than 40% free area, with neat and flat end connection and nose pieces to ensure no added resistance to air flow.

Duct sizes on the drawings are air stream sizes, so allowances must be made for thickness of internal insulation when constructing ducts.

Unless otherwise stated, all supply and return ductwork shall be internally insulated on the first 5 metre length connected to the air handling/fan coil unit.

Fire Rated Ductwork

Duct construction shall be 1.6mm (16 Ga) galvanised sheet metal. In addition, provide encasement of calcium silicate or similar fire rated board after insulation. Fire rated board shall be of authorities approved type and construction shall be such that all joints are properly sealed. All support hangers shall also be suitably fire rated.

In addition, at the point where the duct exits from each fire compartment, for a distance of 500mm in the direction of airflow, the duct shall be constructed of 2mm steel, all joints continuously welded with a 2.5mm thick steel flange securing the duct to the structure at the point of exit.

P.E. certification for all fire rated ducts as constructed shall be submitted by the Subcontractor's P.E. on completion of the work.

Kitchen Exhaust Duct

Provide 2 hour internally and externally fire rated ducts for kitchen exhaust duct where shown on the drawings.

Submit P.E. certification for the fire rated duct and support system on completion of the work.

Access panels and drain taps shall be appropriately located to facilitate maintenance, horizontal duct shall be graded to fall and drain points shall be located at all low points.

Discharge ducts will be fitted with grease trap boxes before connecting to the discharge louvre.

Special Finishes

Ductwork exposed outside or otherwise subject to the weather and elements shall be 0.2mm heavier than otherwise specified. All raw edges shall be filed smooth and corners rounded.

Ductwork exposed in occupied spaces shall be manufactured to give a neat finish. Duct sections having sealant smears, handling damage or heavy scratches will be rejected. Exposed ductwork shall be finished in accordance with clause **PROTECTION AND SURFACE FINISHES,** and **PAINTING.**

Where ducts pass through walls/floors etc., and are in view, escutcheons formed from extruded aluminium angle shall be provided to mask the opening.

All main ducting shall be labelled in accordance with the clause **IDENTIFICATION.**

13. LEAKAGE TESTING

1. General

Subject to the limitations set out in the following paragraphs, at least 10% of horizontal ductwork of each pressure rating and at least 20% of vertical duct risers shall, after installation and prior to being concealed, be tested for air tightness, and the results recorded on test sheets.

Non-metal connections, and items such as air handling devices, terminal boxes, sound attenuators, heat exchangers, are to be blanked off from these tests.

No addition shall be made to the permissible leakage rate for access doors, access panels or dampers where these are included in the ductwork.

Ductwork shall be tested, and records kept, in sections as the work proceeds. No subsequent testing of the system as a whole is required, but joints (including the joints of the flexible ducts) between tested and untested sections shall, as far as possible be checked by external visual examination.

Testing shall be completed before insulation or enclosure of the ductwork and before terminal units (if any) are fitted.

The air leakage rate for any section shall not be in excess of the permitted rate for that section. If a first test produces leakage in excess of the permitted maximum, the section shall be re-sealed and retested until a leakage not greater than the permitted maximum is achieved. In the event of low pressure ductwork failing to meet the initial test the Engineer shall direct that the inspection and testing procedure shall be intensified including additional tests of other duct sections at no additional cost.

2. Leakage Rate

Allowable leakage rate shall be according to duct surface area as set out in SMACNA.

3. Test Apparatus

The accuracy of test apparatus shall be within:

±10% of the indicated flow rate, and; ±5% of the indicated static pressure in the duct under test.

The test apparatus shall be approved by the Engineer before use on site, and shall have a calibration certificate, chart or graph certified by a recognised testing laboratory, not earlier than one year before the test for which it is used.

Attachment to Building Structure

Duct supports and hangers shall comply with the SMACNA Duct Construction Standards. Provide a hanger and support within 300mm of each duct outlet and flexible duct to ensure proper support to branch and flexible ductwork.

All ductwork supported by trapeze type hangers shall be insulated from its hanger or support by a minimum of 3mm felt which is to be held securely in position.

Where insulation and a continuous vapour barrier is required, supports shall not be connected directly to the duct, stiffeners or flanges, but separated from the duct by an insulator (phenolic foam or polyurythane) capable of carrying the imposed load without significant compression to be of equal thickness to the insulation and allow the vapour barrier to be continuous between the support and insulant.

14. DUCT FITTINGS

Bends

All short radius or square bends shall be fitted with internal turning vanes to reduce air turbulence and noise.

Access Panels

Removable access panels for cleaning and inspection shall be provided at the bottom of vertical runs and at fire dampers and control dampers. Covers to panels shall be not less than the duct wall thickness and secured with suitable quick release catches. Panels in ducts under 450mm wide shall be 225 x 225 mm and in ducts over 450mm wide shall be 450 x 350mm. Panels shall be acoustically sealed.

Removable access panels for cleaning and inspection shall be provided at the bottom of vertical runs and at fire dampers and control dampers. Covers to panels shall be not less than the duct wall thickness and secured with suitable quick release catches. Panels in ducts under 450mm wide shall be 225 x 225 mm and in ducts over 450mm wide shall be 450 x 350mm. Panels shall be acoustically sealed.

Test Holes

Provide 12mm diameter test holes for pitot tube scanning in each branch duct. Plug holes with rubber plugs or fit removable screw caps. On large rectangular ducts provide a series of test holes on both sides of the duct located as recommended in the ASHRAE Handbook of Fundamentals.

Balancing Dampers

1. General

Balancing dampers shall be installed in each branch duct and shall be correctly set during testing and commissioning from duct pitot tube readings (branches serving more than ten outlets) and from outlet air flow readings (branches servicing ten or less outlets). Balancing dampers shall also be provided at other locations indicated in the drawings.

Dampers shall be rigidly constructed and free from slack movement or vibration. Construct from 1.6mm (16 Ga) galvanised sheet metal, or plate steel zinc-treated after manufacture.

Spindles shall be of stainless steel of square or round section and shall rotate freely in permanently lubricated low friction bearings. Fix blades centrally to the spindle by rivetted clamps or welding.

2. Splitter Dampers

These shall be single blade of 1.6mm galvanised steel having heavy-weight brass full width hinges with all component hardware of non-ferrous materials. Blade dimensions shall allow sufficient duct wall clearance to avoid noise

generation. The threaded adjusting rod shall be of galvanised mild steel, 8mm minimum diameter.

An indicator shall be provided on the screwed shaft to mark the final adjusted damper position.

Where dampers are to rotate, steel shafts, bearings and fixings to be as described above (in clause (a) General).

3. Butterfly Dampers

Single blade butterfly dampers shall be no wider than 300mm measured at right angles to the spindle. Where the duct depth exceeds 300mm use opposed action multi-blade dampers.

Dampers shall be constructed of 1.6mm galvanised steel dimensioned so as to effectively shut off air flow without generating noise.

Butterfly damper blades shall be made up in two halves, one each side of the spindle to form smooth streamlined shape. As an alternative, single thickness metal blades with minimum 6mm edge breaks may be used, provided the blade width normal to the spindle does not exceed 225mm. One spindle end shall be squared and fitted with a quadrant lever suitably marked to indicate the actual blade position.

4. Opposed Blade Dampers

For duct widths in excess of 300mm, opposed blade dampers shall be used.

Opposed blade dampers shall be constructed with blades of extruded aluminium aerofoil section having edges sealed with neoprene or similar purpose-made moulding. Blades shall be sealed at the ends by damper frame insert pieces of flexible convex aluminium.

Blades of maximum length 1200mm shall be centrally pivoted at the ends with grade 316 stainless steel stub shafts having nylon bearing frames fixed so as to prevent bearing outer housing movement. Spindles shall be round or square section. For widths greater than 1200mm the damper shall be split into two sections.

The damper frame shall be flanged for bolt assembly, easy access and removal.

Each drive linkage shall be attached to the stainless steel shaft with a grub screw through a non-ferrous purpose-made boss into a shaft dimple. A die cast zinc boss is not acceptable.

Damper linkage shall be heavy-weight galvanised mild steel with bronze pins at the pivot points, held in position with heavy-weight snap-lock washers and

galvanised clips. Ductwork access panels shall be provided adjacent to each opposed blade damper for maintenance and inspection purposes.

Each damper blade shall be fitted with a purpose-made damper quadrant which has open/shut indication incorporated in the metal casting/pressing. The quadrants, when fixed in position, shall reach the stop end of the quadrant travel when in the fully open position. An indicator shall be provided on the quadrant to mark the final adjusted damper position. Quadrants of pressed zinc are not acceptable.

5. Pressure Reducing Dampers

Pressure reducing dampers shall be electronically actuated, capable of controlling an air flow with maximum static pressure of 700 Pa, while producing a minimum total pressure drop at full flow within the limits shown in the schedule.

Non-standard size units may be made up of two smaller units fixed together according to the manufacturer's written recommendations.

The damper actuator shall must be compatible with damper operation.

6. Motorised Dampers

These shall have aerofoil shaped parallel blades, generally in accordance with the requirements for Opposed Blade Dampers above. Blade linkages shall be out of the air stream. The damper shall be suitable for motorised operation. The damper linkage shall be compatible with the actuator.

7. Pressure Relief Shutters

Blades shall be formed from steel with vinyl edges and linked by a gang bar to operate in unison. A tension spring shall be adjusted to allow the blades to open at a differential pressure of 50 Pa.

Flexible Branch Ducts

Flexible supply and return air branch ducts shall be carried out in fire proof flexible acoustic ducting which shall be fibreglass insulated and sheathed in fireproof vapour barrier. Length of flexible duct shall be sufficient to allow diffuser to be installed anywhere up to 1000mm away from the position shown on the drawings. Light gauge aluminium foil duct shall not be used.

Fire Dampers

Fire dampers shall be Authorities Approved and rated equivalent to the wall in which they are installed.

Damper housing shall be strongly fixed into the wall in accordance with CP13 so that the failure and dropping off of the duct in a fire does not dislodge the fire damper

from the wall. Incombustible compressable material shall be packed in the gaps between the flanges and the wall material.

The gap between the fire damper housing and the wall shall be closely packed with a fire proof material capable of withstanding a temperature of up to 1100 Degree C. Fibreglass shall not be allowed.

Duct connections to the damper shall be arranged so that expansion of the ductwork in a fire cannot impair the operation of the damper by protruding into the damper housing.

Flexible Connections

Flexible joints shall be fitted to all inlet and outlet connections of all AHU's, fan coil units and fans, and elsewhere as indicated on the Drawings. Flexible joints shall be a minimum effective length of 50mm. In no case shall a flexible joint exceed 100mm in length. Care shall be taken to maintain alignment between the fan and duct connections.

With flanged rectangular connections, the flexible joint shall be held in place by a mating flange.

For spigot connections, the flexible joint shall be held in place with flat bar strips.

A backing plate shall be used with proprietary joints having metal edges. Backing plates shall be not less than 3mm thick.

Adaptors shall be used to provide plain circular ends for spirally-wound ducts. Alternatively, flanged connections may be used, adapting the method set out above, with the joint secured by clip-bands with adjustable screw or toggle fittings.

The material used for flexible joints shall be barium or lead loaded vinyl with a minimum surface density of 4.0 kg/sq m and flameproof. Hemp based material is not acceptable.

Care shall be taken during the installation of flexible connectors to ensure that they do not sag under negative pressure and restrict the contained air flow, particularly on the upstream side of axial flow fans. When flexible connectors are used on the high pressure side of fans, care shall be taken to ensure that extension of the flexible joint does not cause movement of the fan or associated equipment.

15. VIBRATION AND NOISE CONTROL

General

This section covers the general requirements that constitute the attainment of an acoustic comfortable environment within the Building. The requirements stipulated in this part of the Specification shall be in addition to any other requirements which have already been specified elsewhere.

It is the intent of this Specification that noise levels due to mechanical equipment and related services will be controlled to the Design Objectives stated herein, in all occupied areas.

The requirement specified are considered to be the minimum precautions necessary to achieve these objectives. The entire installation shall operate without objectionable noise and vibration as determined by the Architect.

The subcontractor shall engineer his design and installation with due considerations to vibration, vibration-induced noise, airborne noise via ductwork and all air supply and return paths, including the control of all noise breakout via ducts and associated fittings.

The subcontractor should bring to the Architect's attention should any of the requirements, in his opinion, is not attainable. Otherwise the subcontractor shall guarantee that the equipment will operate within the criteria, or bear all costs of remedial work to achieve the Design Objectives.

Machinery and equipment shall be installed so as to ensure that the transmission of tactile and audible vibration to the building due to the operation of that machinery and equipment and/or its connection to pipework, ductwork or conduits, is reduced to the practical minimum.

All rotating parts shall be balanced statically and dynamically to recognised standards.

All rotating parts, or machinery which contains rotating parts, shall be isolated from the building structure via anti-vibration isolators.

Inertia bases shall be provided for machines with large, out-of-balance forces, such as internal combustion engines, air compressors, reciprocating refrigeration compressors, pumps and high pressure fans.

Reinforced concrete houskeeping pads, at least 100mm thick, shall be provided below all major mechanical and electrical equipment which is floor supported.

Installation of vibration and noise control equipment, including spring hangers, shall not obstruct proper equipment access for maintenance.

Pipes and Conduits

Pipework connected to rotating machinery shall incorporate resilient supports, sized to meet the static deflections of the isolators designated for the associated machine for the length within the Plant Room plus the first 20m run outside the chiller plantroom.

Ensure that there is no rigid connection between pipes and the Plant Room wall. A clear opening of 25mm shall be left around all pipes penetrating Plant Room walls, packed with hardness 30 rubber foam sleeves ends with silicone sealant.

Electrical cables carrying power supplies to rotating machinery shall be in a looped form, and not connected via rigid conduits which may short-circuit vibration isolators.

Design Objectives

The requirements based on the usage of the spaces in the building are as follows:

****OPTION - PLEASE COMPLETE IF RELEVANT TO THIS PROJECT****

Space	Maximum Noise Criteria (NC)
Suites (including bathrooms)	35
Living Areas	40
Banquet Room	35
Corridors, Main Entrance Lobby, Lift Lobby	45
Sports Areas	45
Toilets (not in suites)	45
Carpark	45
Offices	40
Banking Hall, Retail	40
Staircases, Fire Lobbies	50
Carpark Lift Lobby	50
All other areas	45
Plantrooms	
- Lift Motor Room	80dBA
- Pump Room	85dBA
- Chiller Room	95dBA
- Other Plantrooms	78dBA

**** OPTION - ENDS ****

All these specified criteria shall apply to all areas as measured at a level 1.5m above the floor. Where AHU rooms are encountered, the measurement shall be at similar height from the floor but at not less than 0.8m and not more than 1.5m from the AHU room walls. Where fan coil units are encountered, the highest noise levels measured under the units will only be recorded.

Where dispute arises over the classification of any area the Engineer's determination shall be final.

The subcontractor shall install all noise-generating equipment and systems based on the above criteria. When the measured noise is rumbling, tonal or groaning the measured NC shall be read as plotted NC+5. When the emitted noise from any equipment carries tonal, rumbling or groaning content, the plotted NC must be 7dB lower than the specified criteria to be considered as meeting the criteria.

Equipment Balancing and Alignment

The subcontractor shall guarantee that all equipment will be installed in balanced and aligned conditions.

Generally, the equipment shall be installed to meet the severity criteria as stipulated in ISO 2373 and summarised as follows:

Equipment	Maximum Allowable Vibration mm/s RMS
Pumps	0.7
AHUs	0.7
Fans	0.7
Chillers	2.8
Compressors	2.3

Fan Coil Units

Refer to clause **FAN COIL UNITS.**

VAV Boxes

All VAV boxes shall be of an approved make with test results from accredited testing laboratories, tested under ADC codes.

All submissions shall include:

8. through unit sound levels

9. through casing sound levels

at all operating conditions.

The through unit sound levels should not exceed the noise criteria of the space it is serving. The radiated sound level should not exceed by more than 3 dB, at all bands, above the noise criteria of the space it is serving. Where the attenuation of the standard lined discharge box is insufficient, the subcontractor shall allow for additional length of internally lined distribution ductwork such that the noise criteria for the space is not exceeded.

Air Diffusers/Registers/Grilles

All diffusers shall be appropriately selected to meet the noise criteria of the space they are serving. Generally two requirements are to be fulfilled:

10. If the diffusers are spaced far apart, each diffuser shall be selected with acoustic performance to meet the noise criteria.

11. If the diffusers are spaced close to each other, group acoustic performance shall be considered for the selection in order to meet the noise criteria.

All diffusers and registers shall be selected with acoustic performance at least 5 dB lower than the criteria of the space they are serving.

The subcontractor shall submit their selections complete with acoustic performance data produced by an accredited testing laboratory.

Spring Vibration Isolation System

All spring vibration isolators shall be free-standing, unhoused, laterally stable steel springs assembled into upper and lower load plates and complete with minimum 8mm thick neoprene acoustical friction pads between the base plate and the support. Where necessary multiple layers of neoprene pads shall be used.

Spring diameters shall be no less than 0.8 of the compressed height of the spring at rated load. Springs shall have a minimum additional travel equal to 50% of the rated deflection before they become fully compressed.

All mountings shall be rigidly bolted to the equipment.

Where restrained spring isolators are to be used, housing shall include vertical limit stops to prevent spring extension when weight is removed. A minimum clearance of 13mm shall be maintained around restraining bolts, and between the housing and the spring so as not to interfere with the spring action. Limit stops shall be out of contact during normal operations.

Mountings used out-of-doors shall be hot-dipped galvanised by the manufacturer.

Isolator Hanger

Such hangers are to be used for resilient suspension of pipes and ducts, where specified.

For specified deflections in excess of 12mm, spring-neoprene-in-series type shall be used, and for deflections less than 12mm, neoprene-in-shear type hangers shall be used.

All pipe connected to mechanical equipment in the plantroom are to be isolated by isolation hangers.

All hangers in the chiller plantroom plus the first 20m run outside the chiller plantroom shall be of spring hangers. Beyond these hangers, double-deflection neoprene-in-shear hangers may be used. All hangers in the equipment room shall have a minimum static deflection of 50% of that specified for the equipment which the pipes are connected to.

Hangers length shall be minimised. Hanger rods should be anchored to beams. Anchorage to slabs, where possible, should be avoided. Parallel running may be isolated on a trapeze configuration support system.

Vibration Isolation Pads

Where waffle or ribbed neoprene pads are to be used, select 50 or 60 durometer pads to suit the required loading. Where multiple-layer pads are selected, the layers are to be separated by 1 to 1.2mm thick steel shims.

Inertia Block Base

The subcontractor shall supply and install concrete inertia base to centrifugal fans (excluding AHUs), centrifugal pumps and close coupled pumps.

The inertia base construction is generally as shown in the detail drawing. All perimeter members shall be steel channels with a minimum depth equal to one-twelfth of the longest dimension of the base but not less than 150mm deep.

The weight of the inertia base is to be determined by the inertia base/equipment mass ratio as stated in the clause for each item of equipment.

Pipework Connectors to Pumps, Chillers and Cooling Towers

All pipework connecting to any vibration source shall be flexibly connected with approved limiting device.

All pipework to pumpset shall be connected with twin-sphere flexible rubber-neoprene connectors or stainless steel bellows (as appropriate to the size and pressure duty).

Material shall be suitable for the application in consideration of the chemical treatment of the water.

Sound Attenuators

Sound attenuators shall consist of an outer casing, aerodynamically designed splitters, sound absorbing material and supports. The casings shall be of galvanised steel of 1.2 to 1.5mm. End flanges shall be made from galvanised mild steel sheet or rolled steel angle. Duct sealing compound shall be furnished by the subcontractor for sealing of all sound attenuators on-site where necessary, to the Engineer's approval.

Sound absorbing material shall be fibreglass (32 - 40kg/m^3) or mineral wool (50 - 60kg/m^3) held in place, with at least 5% compression to prevent voids due to setting, and faced with 0.5 to 0.8mm thick perforated galvanised sheet metal of 23 - 30% open area. No perforated holes shall exceed 3mm diameter. Sound absorbing material shall conform to BS 476 : Part 7 (1971) "Surface Spread of Flame" Classification 1 or combustion rating in accordance with ASTM E84.

The Subcontractor shall submit the certified manufacturer's data on dynamic insertion loss and self-noise at the specified peak airflow. Static pressure loss of sound attenuators shall not exceed those listed in the equipment schedules. The minimum dynamic insertion loss required are given in the **EQUIPMENT SCHEDULE**.

Ducts

Ducts shall be constructed such that drumming does not occur.

Compliance Test

Compliance tests shall be carried out by the Sub-contractor to demonstrate to the Engineer that the installation has fulfilled the stipulated requirements and criteria.

They shall be carried out when the mechanical equipment is at specified operating condition.

The measurements shall be witnessed by relevant parties including the Engineer's representative. The subcontractor shall submit the test programme and schedule to the Engineer for review. Give the Engineer at least one week notice of any compliance test.

Should it be found that compliance has not been achieved, additional work may have to be carried out to rectify and/or modify the installation to meet the specified criteria. All further work and additional testing, where necessary, shall be conducted at the subcontractor's own cost.

16. VARIABLE AIR VOLUME SYSTEM

General

The variable air volume system shall include pressure independent, throttling type variable air volume (VAV) terminal units with variable speed control of the air handling unit fan motors.

Variable Air Volume (VAV) Terminal Units

VAV terminal units shall be pressure independent type, maintaining the required supply air quantity in response to the thermostat setting regardless of the VAV unit inlet or system pressure, temperature or humidity.

The VAV unit casing shall be of galvanised steel and internally insulated with 25mm thick, 24 kg/cu m density fibreglass and coated to prevent erosion.

Factory fabricated discharge plenums complete with 5 spigots, internally lined with 25mm thick 24kg/m3 fibreglass, shall be provided for each VAV unit. Each spigot shall be ∅200mm and shall include a butterfly balancing damper.

The controls components for each unit shall be electronic and shall include a velocity sensor, velocity controller/damper actuator and temperature sensor and controller.

The required supply air quantity shall be determined by the temperature controller setting (and the room load) which shall send a signal to the velocity controller to control the supply air quantity via the damper actuator and velocity sensor. The damper actuator shall be powered by electricity.

Adjustment of temperature set point and air flow limits shall be done at the temperature controller.

Include all control cabling, transformers and sensors for complete operation of the system, complete with one temperature sensor per VAV unit.

Air Handling Unit Fan Variable Speed Control

The supply air quantity of the AHUs shall be varied in response to the capacity required at the VAV terminal units by controlling the speed of the fan motor. This shall be done by varying the frequency using AC invertor control. The pressure sensors sense the

pressure at the control points and transmit a signal to the variable speed controller to reduce the speed of the motor when the lowest of the pressures at the system control points increase due to VAV terminal units closing. Allowance shall be made for relocating the pressure sensor to an optimum position. The VAV system shall be commissioned in accordance with CIBSE or ASHRAE methods.

17. CONTROL SYSTEM

General

All control instruments shall as far as possible be by a single manufacturer and be installed and commissioned by a specialist with at least 5 years experience in air-conditioning controls.

The proposed method of control shall be outlined briefly in the tender submission. All detailed equipment selections of the acceptable system shall be submitted along with a system schematic and all data such as but not limited to component makes, ratings, initial settings, ranges proportional/dead bands etc.

Central Plant Control Panels

(Chillers, Pumps, Cooling Towers)

The basis of the tender shall be for a micro-processor based controller suitable for programmed start/stop, optimisation, and alarm monitoring.

The micro-processor shall be located in a separate compartment of the central plant motor control centre located in the plantroom, and shall perform the following specific control functions.

1. Act as the building central clock for scheduling of all chillers, boilers, pumps, cooling towers and motorised valves in the plantroom and on the roof.

2. Direct digital control (DDC) of all central plant and perform all calculation for PID/optimisation routines.

3. Monitor alarm status on chillers, pumps and cooling towers.

Controllers shall be of the 'programmable point' type, and shall have 30% spare input/output points. The controller shall be capable of RS 232 communication in the future with a micro-processor based BMS.

All central plant rotary switches at the motor control centre shall be three position type ON/OFF/AUTO such that when in the 'auto' position, the micro-processor shall provide the necessary control signal.

Components Material and Installation

The scope shall include supply and installation of the following:

4. Control Circuits
5. Control Cabling
6. Contactors
7. Auxiliary Contacts
8. Temperature Sensors / Thermostats
    -Duct
    -Water
9. Flow switch
10. Controllers
11. Actuators
12. Control Valves
13. Step Controllers
14. Solenoid Valves
15. Indicating Lamps
16. Interposing Relays
17. Control Switches
18. Velocity Controllers
19. Float Switches
20. Flow Meters
21. and all other accessories / devices necessary for the proper functioning of the works

Description of Controls

For VAV AHUs control sequence refer to clause **VARIABLE AIR VOLUME SYSTEM**. CAV AHUs shall modulate the cooling coil control valve to maintain constant return air temperature of 23^0C (adjustable).

1. Low Load Chiller CH-4

The start sequence shall be as follows :-

Receive start signal

Open low load chiller CH-4 chilled water motorised valve.

Start chilled water pump CHWP-4 and verify flow by positive response from flow switch.

Monitor return chilled water temperature for 20 seconds (adjustable and verify if less than or greater than 8^0C (adjustable decision point).

If more than 8^0C continue start sequence as below.

If less than 8^0C do not continue start sequence. Leave chilled water pump on and continue to monitor return chilled water temperature. When temperature rises above 8^0C continue with start sequence as below.

Open chiller CH-4 condenser water motorised valve
Open duty cooling tower motorised valve (if not already open for tenant/after hours condenser water circuit).

Start duty cooling tower (fans) if not already operating.

Start condenser water pump CDRP-4 and verify flow by positive response from flow switch.

After suitable time delay (adjustable) provided all conditions above are satisfied, start chiller CH-4.

Allow chiller to modulate on packaged control to achieve design chiller water supply temperature of 6.7^0C.

Should the chilled water load fall below 20% (adjustable) of the chiller rated capacity the chiller stop sequence shall be initiated except that chilled water pump shall continue to run.

Should all AHUs be turned off the stop sequence shall be executed.

Stop sequence shall be the reverse of the above with appropriate time delays. Note that before turning off the cooling tower, check if required for tenant/after hours circuit - if required, leave cooling tower on.

2. Tenant/After Hours Condenser Water circuit

This shall normally operate 24 hours per day with one pump on. The initial start up sequence shall be as follows :-

Receive start signal

Open duty cooling tower motorised valves (if not already open)

Start duty tenant condenser water pump (duty pump determined by lowest run/hours) and verify flow by positive response from flow switch.

Continuously monitor flow switch. If flow fails then raise an alarm, turn off the duty pump and turn on the standby pump.

Rotate duty and standby every 24 hours (adjustable to one week).

Variable speed drives are intended to be manually set depending on the changes in connected load as tenants carry out alterations.

3. Ventilation Fans

Fans start/stop shall generally be by time signal.

Where shown on the drawings, fans shall be treated as duty/standby with one only operating at any time. Rotate duty/standby designation every 24 hours (adjustable to one week). Monitor room temperature and if above a (adjustable) set point temperature then raise an alarm and stop duty fan and start standby fan. Initial set point shall be 40^0C. If a trip fault is detected in duty fan then raise an alarm and stop duty fan and start standby fan.

Control of FCUs

Refer to clause **FAN COIL UNITS** for details.

Control of Variable Speed Pumps for Secondary Chilled Water Loops

A proprietary microprocessor based controller designed for pumping application shall be provided for each secondary pump. The controller may be permitted to have several channels to facilitate multiple pump control, however, channels shall be arranged such that duty and standby pumps are not configured on the same controller. The intention is to avoid the case where a faulty controller renders both duty and standby pumps inoperative.

The controller shall be compatible with the pressure sensing system, flow measuring equipment and the variable speed drives.

The controller shall be field programmable and have capable of bi-directional communication with the future BMS system using RS232 ASCII serial format.

All information about pressures, voltages, flow rates shall be able to be transmitted to the BMS via this communication. Liaise with the BMS subcontractor to effect the communication.

Each secondary pump speed shall be controlled to achieve a constant differential pressure across the differential pressure. The differential pressure sensors shall be sufficiently sensitive to enable stable operation across the whole range of flows. Unless otherwise specified, the stable range if flow is from 100% down to 15% of the design flow.

Details of the proposed variable speed pumping control system shall be submitted with the tender.

18. CONTROL COMPONENTS AND MATERIAL

General

As far as possible all control equipment shall be from a single manufacturer. All components shall be 230V type. Provide complete control system which includes sensors, relays, contactors, motorised equipment etc.

Control Circuits

Connection diagrams shall be prepared showing all devices, wire and terminal numbers which shall be fixed with a permanent marking system to the equipment when constructed. Circuit diagrams shall be included in As-Built drawings.

Auxiliary Contactors

Auxiliary contacts shall be potential free for monitoring and/or control purpose of the equipment.

Damper Motors

Motors shall be 230V complete with motor mounting bracket and fully adjustable damper linkage from the same manufacturer.

Type: Honeywell, Sauters.

Field Devices

1. General

All field devices shall be robust in construction, suitable for use in environmental conditions of 0° - 50° C and 10% - 90% relative humidity (non-condensing).

The devices shall operate on 4-20mA signals and shall be adjustable for calibration. Set points shall be adjustable from 0 - 100% of the input range.

Analogue devices shall provide long-term accuracy without need for regular calibration.

A binder test point shall be installed in the pipework adjacent to each sensor point for manual testing of pressure and/or temperature.

2. Temperature Sensors

Temperature sensors shall be factory calibrated and shall not require compensation for cable lengths, etc. Accuracy of sensors shall be ±0.3°C.

The following working range shall apply.

Location of Sensors	Range
Room	15 to 30°C
Duct	5 to 40°C
Outside Air	10 to 40°C
Chilled Water	3 to 20°C
Condenser Water	10 to 40°C
Heating Water	50 to 85°C

Room temperature sensors shall each consist of a transmitter with an integral sensor. They shall have tamper-proof covers. They shall have vents for air circulation. Where wall-mounted they shall be sealed from cavity space behind the wall surface and be mounted on insulating pads.

Outdoor sensors shall be provided with weather-resistant elements.

Duct mounted sensor shall consist of a transmitter and a remote sensor. The transmitter section of the transducer shall be mounted on the outside of ducts clear of insulation and sheathing and have a tamper proof cover.

The sensor shall have a separate mounting flange with snap on connection to permit sensor removal for site calibration and service, and shall be protected from physical damage, dust and moisture.

It shall have a minimum insertion length of 200mm, with temperature averaging along its entire length. The sensor shall be mounted in the duct in a position that senses the true average temperature of the air in the duct.

Conditioner mounted sensor shall consist of a transmitter and a remote averaging sensor.

The transmitter section of the transducer shall be mounted on the outside of conditioner housing clear of insulation and sheathing and have tamper proof cover.

The sensor shall have a separate mounting flange with snap on connection to permit sensor removal for site calibration and service, and shall be protected from physical damage, dust and moisture.

The averaging sensor shall be mounted in the conditioner housing in a position that senses the true average temperature of the air in the conditioner

Immersion type sensors for pipe or tank insertion shall be sufficient length to ensure accurate measurement and shall be installed in wells designed to permit easy removal for inspection or repair.

Wells shall be of minimum 100mm depth stainless steel and be designed to suit the sensor so that response time remains suitable for the application. The sensor shall be in thermal contact with the immersed surface of the well.

Wells for insulated pipework shall have sufficient length to ensure that sensor removal is not hindered by the insulation and wells shall be mounted such that condensation does not run into the sensor head.

The transmitter section of the transducer shall be mounted adjacent to the well in which the sensor is mounted.

It shall be possible to remove the transmitter and/or the sensor without removing the well from the pipe.

3. Humidity Sensors

Humidity sensors shall have an accuracy of ±3% RH over the range of 10% to 95% RH and over the temperature range of 0° - 40°C.

The sensors shall be maintenance free and immuned to moisture saturation. Sensors shall be capable of being periodically cleaned by washing or a similar process, without degrading the performance or reducing the expected working life.

Wall mounted humidity sensors shall each consist of a transmitter with an integral sensor. They shall have tamper proof covers, and shall be mounted on insulating pads. They shall have vents for air circulation, and shall be sealed from cavity space behind the wall surface.

Outdoor sensors shall be provided with weather-resistant elements.

Duct mounted sensors shall have minimum insertion length of 200mm, and shall have separate mounting flange with snap on connection to permit sensor removal.

They shall be protected from physical damage, dust and moisture.

4. Pressure Sensor

Internal materials of pressure sensors shall be suitable for continuous contact with the gas or liquid which the sensor is measuring.

The span shall be greater than the specified working range, with accuracy of ±0.1% of the specified range or 0.25% of the span, whichever is lesser.

The transducer shall be protected against over pressure to a minimum of three times the rated working pressure.

Pressure sensors shall be mounted in accessible locations where the effects of turbulence etc. will not cause unsatisfactory operation.

Air differential pressure sensors shall be fully solid state and shall utilise the hot wire technique to measure air velocity through a calibrated orifice and shall compensate for temperature changes in the measured air temperature. Sensors shall be able to operate on positive or negative pressures.

The sensors shall have separate duct mounting flanges with snap on connection.

Liquid pressure sensors shall be suitable for use on the application (water, steam or refrigerant). They shall employ bellows sensing elements and shall provide a proportional output of the measured pressure. Pulsation snubbers shall be provided. Where pressure differences are to be measured the sensors shall be mounted at the same height.

5. Water Flow Sensor

Water flow sensor shall be of electromagnetic type and consist of two parts: primary measuring unit and the converter. The primary measuring unit shall have no moving parts or intrusion into its flow path. It shall be lined with neoprene, artificial ceramic or better liner. The primary housing shall be of at least IP65 protection.

They shall be mounted in accessible locations where the effects of turbulence etc. will not cause unsatisfactory operation.

The converter shall give an adjustable 0 to 1 KHz pulse output corresponding to the flow quantity.

Overall accuracy of the flow transducer shall be ±0.5% full scale.

6. Pressure Switches

Pressure switches shall be capable of withstanding damage from the maximum pressure developed by the system in which they are installed. This shall include fan or pump shut-off pressure where applicable.

They shall be mounted in accessible locations where the effects of turbulence etc. will not cause unsatisfactory operation.

Switch outputs shall be volt-free contacts with adjustable set point and differential to suit the required working range.

Where differential pressure switches are required, switches shall have dual pressure inputs arranged to sense the required differential pressure.

7. Float Switches

Float switches shall be mounted in an accessible position. They shall provide volt-free contact outputs with adjustable differential and be suitable for installation in the nominated fluid.

8. Level Probes

Level probes shall provide a volt free contact output. The probes shall be suitable for mounting in the nominated fluid.

9. Water Flow Switches

Water flow switches shall be of the paddle type, and shall be mounted in accessible locations where the effects of turbulence etc. will not cause unsatisfactory operation.

Switch outputs shall be volt-free contacts.

10. Position Switches

Valve position switches shall be capable of being displayed in percent open notation.

11. Electric Actuators

The input signal to the actuator shall be selectable at the motor for 4 - 20 mA. The output shaft of the actuator shall be rotated between the limits of its travel directly proportional to the input signal. The actuator shall be fitted with a manual operator such that, in the event of a power failure or other failure, manual operation can be achieved.

Reversible actuators shall include limit end switches to prevent damage to the electric actuators. Continuous feedback shall be employed to position the motor shaft relative to input signal.

The actuator shall have a feedback signal indicating shaft position available as an output. This signal shall be connected as an analogue input to the digital controller.

Actuators shall provide a linear (push-pull) thrust without the use of cams, gears or linkages, and shall not require maintenance or readjustment.

Actuators shall be electro-servo or electro-hydraulic type and shall have a minimum number of moving parts.

Actuators shall incorporate electronics to positively position the output device in accordance with the control signal. The electronics shall incorporate an additional input for remote override or minimum positioning.

Damper actuators shall be provided with all necessary mounting brackets, push rods, etc.

Valve actuators shall mount directly on the control valve without the need for separate linkages and the need for any adjustment of the actuator stroke. Actuators shall have a manual operation capability. The actuator electronics shall incorporate a selector to change the valve-plus-actuator flow characteristic from an equal percentage to a linear response.

12. Control Valves

Control valves shall be of the modified linear or equal percentage type and be suitable for the temperatures and pressures of the particular services in which they are installed. Valve bodies shall be of bronze or cast iron with stainless steel trim and renewable discs and seats.

Control valves 50mm and below shall be threaded connection. Valves 65mm and above shall be flanged. Valves shall be available with a body pressure rating of greater than 16 bar (except if higher pressure is specified elsewhere) and rangeability of better than 100:1.

Threaded valves shall be of gunmetal (bronze) and flanged valves of cast iron or cast steel.

Threaded valves shall be provided with pipe coupling pieces.

All valves whether two port or three port shall be closed when the spindle is in the up position. Two port valves shall have an equal percentage control characteristic. Three port valves shall have an equal percentage characteristic on the through port and a linear characteristic on the bypass port.

Valves shall be sized to have a full flow pressure drop equal to or greater than the pressure drop through the water coil being controlled, but not more than 50 kPa.

Two port valves shall have a close off capability equal to or greater than the maximum possible system differential pressure. (As determined by the pump head or the system differential pressure bypass control setting.)

Three port valves shall have a close off capability equal to or greater than the combined full flow pressure drops of the coil plus the valve itself.

Two port control valves for differential pressure bypass control applications shall be sized to handle at least the full flow of one chiller at the desired pressure setting. The valve shall be capable of closing off against this pressure and of operating at this pressure for long periods without internal wear, or noise.

The supplier shall submit the sizing calculations for all control valves.

13. Current Transformers

Current transformers shall comply with BS 3938 and shall be Class 2. They shall be of the encapsulated type with 5A secondary windings and shall be suitable to withstand the maximum fault current applicable to the switchboard in which they are installed. They shall be selected so as to produce a 5A output when the measured current is approximately 150% of the full load current.

Current transformers shall be protected against open circuits caused by removal of the measuring transducer.

14. Electrical Transducers

Electrical transducers for kW, ampere, voltage and frequency metering shall be of the electronic type with an accuracy class of no more than 2% over the entire output range.

Isolation between input and output shall be rated to withstand 2kV and outputs shall be 4 - 20 mA (linear).

15. Current Transducer

The output of the transducer shall be directly proportional to a change in current input over the entire rated span of the transducer. The input to the transducer shall be 0 - 5 amp from a current transformer.

16. Voltage Transducer

The input to the transducer shall be from a potential transformer. The output shall be directly proportional to a change in voltage input over the entire rated span of the transducer.

17. Watt Transducer

The inputs to the transducer shall be 0 - 5 amp from current transformer(s) and voltage of the phase(s) measured. The output shall be proportional to measured power, taking account of power factor.

18. Watt-Hour Transducer

The pulsed output of the transducer shall be volt-free. Open collector transistor type shall not be acceptable. 1.0 KWh shall be represented by one (1) pulse and there shall not be more than five (5) pulse per second.

The inputs to the transducer shall be 0 - 5 amp from current transformer(s) and voltage of the phase(s) monitored. The transducer shall be suitable for unbalanced loads.

19. BUILDING MANAGEMENT SYSTEM INTERFACE

It is intended to have a Building Management System (BMS) to facilitate monitoring, trend logging, maintenance management, energy management, utilities consumption monitoring, fault monitoring, status monitoring of all equipment.

The ACMV subcontractor shall supply, install and wire all the field devices and interface points namely but not limited to thermostats, temperature sensors, humidity sensors, modulating control valves, dampers, actuators, flow meters, flow switches, differential pressure sensors, position switches, electrical transducers, control relays, current transformers and any other field devices and interface points not specifically mentioned but necessary for the BMS to perform the control, monitoring and measurement functions listed in the attached point schedule.

Wiring from all field devices shall be to an interface terminal board (ITB) supplied and installed in this subcontract. Generally one ITB shall be provided in each plantroom and shall contain a series of labelled terminal strips to which the field devices are to be wired. All field devices shall be verified with the BMS subcontractor for final compatibility co-ordination but generally the input/output requirements of all field devices shall be of the 4-20 mA linear type. The ACMV tenderer shall advise in the tender submission if any field device requires different from 4-20mA linear type.

All wiring shall be at least 18 AWG twisted and shielded and shall be run in metal conduit/trunking.

The ACMV subcontractor is to work and co-ordinate with the BMS subcontractor ensuring that the desired control, monitoring and measurement functions listed in the point schedule are achieved.

The BMS subcontractor will be responsible to provide the software and application programmes necessary for the proper functioning of the desired control sequences. All testing of control sequences shall be done in the presence of both the ACMV subcontractor and the BMS subcontractor.

However in view of the performance nature of the systems, and in the case of the safety systems the statutory requirement to have hard wired control, all system control shall be included in the subcontract.

The scope of work interface is clarified as follows:

1. Plant status and fault monitoring shall be by the BMS subcontractor.

2. Measurement of electricity consumption of main plant (ACMV tenderers are to allow sufficient space for current transformers in switchboards manufactured under this sub-contract) shall be by BMS.

3. Water temperature monitoring across all heat exchangers. (ACMV tenderers to allow for all sockets/pockets to be welded into pipes to suit the BMS subcontractors requirement under this subcontract.)

4. Control of space temperature in all areas is included in this subcontract. All chilled water control valves and actuators shall be included in this subcontract. All humidity and reheat control shall be included in this subcontract.

5. Control of duct static pressure in the case of variable air volume systems. AC variable speed drives shall be included in this subcontract. Temperature control of VAV boxes is included in this subcontract.

6. Monitoring status of all fans. Voltage free contacts to be provided in this subcontract for all equipment to allow BMS monitoring of status and fault, and receive a start stop signal from the BMS. Life safety systems shall be hard wired in this contract, however volt free contacts and selector switches shall be provided to facilitate future BMS connection.

7. Expansion tank level monitoring shall be carried out in the BMS subcontract.

8. Calculation of building air-conditioning load shall be carried out in the BMS subcontract.

9. Scheduling of maintenance for all plant installed under this contract shall be provided by this subcontractor to the BMS contractor to generate scheduled maintenance sequences.
10. Control duty cycling and sequencing of central plant airconditioning shall be included in this contract. Volt free contacts shall be provided for all plant to facilitate automatic operation start/stop signals to control plant in the future.

11. In all cases other than listed above, for all equipment, an Interface Terminal Board (ITB) shall be provided in this subcontract for all equipment, plant and system monitoring points as specified in the BMS Points Schedule. All signals shall terminate in a voltage-free terminal block strip. Such ITBs shall be provided for in every plantroom. Where plant is remotely mounted, the ITB shall be located in the nearest plantroom or adjacent to the control panel. All cabling between the ITB and control panel/equipment shall be included in this contract. All terminals shall be clearly labelled and a circuit designation plan shall be permanently fixed to the inside of the ITB door.

20. ELECTRICAL WORK

Scope

This section of the subcontract includes the supply, installation, painting, wiring, termination, testing and commissioning of all electrical equipment and controls necessary for the proper functioning of the works of this subcontract, and in particular the following:

1. All switchboards, remote control panels, sub-boards, etc., and all wiring from these boards to equipment.

2. Wiring from distribution boards or local isolators provided by the electrical services subcontractor to equipment.

3. Earthing

   The subcontractor shall supply, install and connect all earth continuity wiring for effective earthings of the whole electrical installation under this scope in accordance with the requirement of the Singapore Standard CP-5 and to the Requirements of the Local Authorities.

   All points and equipment shall be earthed with the appropriate circuit protective conductor (cpc), the minimum size of which shall be in accordance with the requirements of CP5.

   All final circuit protective conductors shall terminate at their respective board's earthing bar.

4. All electrical controls including sensors, relays, contactors, protection gear and associated control wiring.

Refer to the drawings and the rest of the specifications for interfaces between this subcontract and other subcontracts.

The subcontractor shall allow fully in his Tender Price for attendance during the commissioning of all equipment involved with the electrical and control installation to ensure optimum performance of the overall system, and for attendance on other parties involved the control and electrical system.

All electrical work shall comply with CP5:1988 and all the amendments thereto.

Unless otherwise shown on the drawings wiring shall be:

a. PVC insulated multi-stranded cables enclosed in solid drawn rigid steel conduits or sheet steel trunking, or

b. Heavy duty mineral insulated copper sheathed cables on perforated galvanised steel cable tray, or

5. Fire resistant cables in sheet steel trunking or on perforated galvanised steel cable tray.

All cables for main power shall be of a size capable of carrying the planned load in accordance with the relevant Code of Practice, using the appropriate derating factors

for temperature and site conditions and taking into consideration the permissible voltage drop.

There shall, as far as possible, be no joints in cables between terminations. Where joints are required due to long runs exceeding 100 metres, appropriate jointing boxes specifically designed for this purpose shall be used. No reduction of the strands for this purpose shall be allowed. No reduction of the strands forming the conductors will be allowed at switch or other terminals, but all the strands shall be efficiently secured by screws, nuts and washers or other approved means.

All electrical equipment shall be fully tropicalised.

All control circuits shall be protected by fuses or equivalent means independent of the protection for the main circuits. All control circuit wires shall be terminated by soldering or clamping in such a way that the wires are not damaged. Accessible terminals suitably marked shall be provided for the attachment of incoming and outgoing cables.

All motors and other items of controlled equipment shall be provided with breakers, starters, contactors, isolators, time switches, timers, and with automatic and/or manual controls etc., to form a complete working system.

Electrical Power Supply Voltage and Frequency

The electricity supply shall be nominal 400V/230V, 3 phase 4 wires, 50Hz operating with a solidly earthed neutral.

The local power authority refers to the POWER SUPPLY PTE LTD OR POWER GRID PTE LTD.

Switchboards and Control Panels

1. General Requirements

The switchboard shall be of the Form 3 cubicle type, totally enclosed, floor mounted, extensible, flush fronted and of the heavy duty industrial type.

The switchboard shall be constructed without any sag and deformation and shall be capable as a whole of withstanding without damages the electrical, mechanical and thermal stresses likely to be experienced under the short circuit current as indicated on the drawings.

All components shall be suitable for indoor use under tropical conditions. The general equipment arrangement of the switchboard shall be as indicated in the drawings. This however shall not restrict the manufacturers from submitting alternative arrangements but will be subjected to the Engineer's approval.

2. Construction

Each cubicle framework shall be fabricated from rolled steel angle sections and shall be self-supporting when assembled, of standard size, uniform in

height and depth. The cubicle panel shall be fabricated from minimum 1.6mm thick sheet steel with turned edges to the front panels and so framed as to provide a clean, flush and rigid construction without welded cross- struts. After fabrication the cabinet shall be thoroughly rubbed down and treated with an approved rust inhibiting primer.

Proper and adequate ventilations shall be provided to each cubicle such that the ambient air temperature within the cubicle, with the breaker/equipment dissipating the heat at rated current, shall not exceed 40°C under all normal operating conditions.

Mechanical forced cooling shall be used where necessary. The cost of such provisions is deemed to be included in the tender price.

Rear and side panels shall be fixed with self-attached screw and of door panel type.

Full access shall be provided to control equipment inside cubicles by means of suitable doors with concealed type hinges. Latching bars shall be of a substantial cross-section and fitted with adequate guides to prevent distortion during operation.

The exterior surface of all cubicles shall be finished semi-gloss grey unless otherwise instructed by the Engineer except those parts normally left bright which shall be cadmium plated and operating parts finished matt black.

The interior of each cubicle shall be finished matt white and shall be dust, insect and vermin proof. The interior of each piece of equipment shall be clearly marked to show the phases. Either coloured plastic discs screwed to fixed components or identification by means of coloured plastic sleeving shall be employed. Plastic tape will not be permitted.

Insulating barriers and shrouds shall be provided around busbars and terminals so that it is possible to work on a dead circuit while the adjacent circuits are still live and to avoid accidental contact.

The switchboard shall be factory assembled and tested before delivery to site in sections for installation.

3. Equipment Mounting

All switchgear shall be mounted on angle steel supports and fitted with escutcheon plates. Fuses shall be mounted on insulating panels fixed to the cubicle framing with mild steel brackets.

Instruments, indicating lights, rotary switches, etc., shall be mounted directly on a fixed fascia panel suitably stiffened to hold them firmly under all conditions of operation.

Relays, contactors, time switches etc. shall be mounted in a separate section or panel away from the power circuits.

4. Busbars and Secondary Wiring

Busbar markings and arrangement, connections and grade of copper shall all comply as appropriate with BS 158, 1433 and 1989.

For breaker rated 300A and above, busbar connecting to main bar shall be provided. The busbars shall be so arranged that they run horizontally through each sectionalised length of the cubicle. Busbars shall be of uniform cross-sectional area, fabricated from Hard Drawn High Conductivity Copper and rigidly mounted on non-hygroscopic insulators. Connections from the busbars to the switches and circuit breakers shall be by means of copper bars securely clamped to the busbars and identified by means of coloured plastic sleeving or painting to indicate the phase colours. All joints in busbars shall be bolted or clamped with contact surfaces suitably prepared to prevent corrosion in service.

Ratings for the main phase and neutral busbars shall be as shown on the drawings provided, but in any case a current density of 1000 Amps per 645mm sq sectional area shall not be exceeded.

All secondary wiring shall be 1000 volt grade multistrand copper PVC insulated cables of minimum 1.5mm square cross-sectional area. Wiring shall be arranged in a neat and systematic manner with cables supported clear of panels and without cross-overs. Bushes shall be provided as necessary to prevent chaffing of cables. Wiring shall be correctly colour coded for ease of identification and shall terminate in an approved type of labelled termination block. No connections or soldered joints shall be permitted.

5. Cable Arrangement

The switchboard shall be designed for top or bottom entry for cables as shown on the drawings. Copper bars for breaker rated 300A and above, or cables for breaker rated below 300A, shall be fixed inside cubicles by switchboard manufacturer to interconnect all switchgears to suitable terminals mounted immediately adjacent to cable terminations at the base of cubicles.

All wiring in the switchboard shall be of 1000 volt grade copper PVC insulated cables and arranged in a neat systematic manner using proper wiring retaining straps. Cables should be properly colour-coded with numbered PVC sleeves at both ends. Cable supports shall be provided to relieve the terminations of any stresses.

Cable end boxes shall be provided for underground cable with the sheath bonded and earthed through a special earthing system.

Where single core cables are installed, brass plates of sufficient thickness shall be provided to serve as gland plates and these shall be effectively earthed.

6. Meters And Instruments

Meters, instruments and relays for external panel mounting shall be of flush pattern, with square escutcheon plates finished matt black. Indicating instruments shall comply with BS 89 and/or IEC 51, IEC 414, IEC 529. They shall be of accuracy Class 1. Scale shall be of length 90 degree with external zero adjustment. Integrating meters shall comply with BS 5685. Kwh meter shall be of direct reading type.

Instruments, meters and relays located on the front of the switchboard shall be so positioned that as far as possible, each instrument, meter and relay is adjacent to the unit with which it is associated. Meter panels shall be hinged to provide ready access to connections and small wiring shall be enclosed in flexible plastic conduit. All meters and instruments shall be fully tropicalised. All terminals shall be completely insulated and potential circuits shall be suitably fused.

Removable or hinged covers shall be provided with dust exclusion gaskets. Protective instruments shall be provided with provision for locking to prevent unauthorised adjustments to the settings. Where vibration are present arising from electro-mechanical devices in the vicinity, the meter/instruments shall be mounted on vibration absorbing material to prevent malfunctioning of the devices.

Voltmeters shall be provided with selector switches for phase-to-phase and phase-to-neutral voltage indication

Ammeters shall be provided with selector switches for indication of all phase currents.

7. Current Transformer (CT)

Ring-type current transformers of appropriate ratios and classes shall be provided for the operation of measuring, protection and supervisory equipment.

Unless specified otherwise on drawings, current transformers for meters and instruments shall have accuracy class 1 and burden not less than 15VA.

Protective relays current transformers shall have accuracy class 5P10 and burden not less than 15VA.

Where the limits of the protective relay and/or meter/instrument burdens are exceeded, the CT burden rating shall be upgraded to suit.

The cost of the necessary upgrading is deemed to be included.

All CTs shall be of correct dimensions for fixing in busbars and shall be manufactured to BS 7626 and/or IEC 44, IEC 185.

All CTs shall be capable of withstanding the maximum prospective primary short circuit current for 3 seconds.

The maximum spill current of the protective relay CT group at rated CT current shall not exceed 0.001% of the CT primary current.

CTs for voltage operated relays shall have knee point voltage of at least twice the required relay voltage setting.

The excitation curve, the magnetising current at relay settings, the secondary winding resistance and other relevant data of the protection CTs shall be selected to ensure that the required relay operating conditions are met.

8. Indicator Lamps

Indicator lamps utilised in switchboards and distribution boards shall be of the transformer type, fitted with coloured lens and flush mounted in door panels. Double filament long life low voltage lamps of suitable voltage rating shall be used.

Indicator lamps used to indicate the 'Phase' of the 3-phase supply shall have coloured lens of red, yellow and blue to indicate 'Red Phase', 'Yellow Phase' and 'Blue Phase' respectively. For indication of motor operating status, coloured lens of indicator lamps shall be green for indicating 'motor running', amber for 'motor tripped' and red for 'motor stopped' conditions. For indicating operation of contactors other than motor starting contactors, indicator lens shall be of green colour to indicate 'contactor closed' condition. Unless otherwise specified, each lamp shall be provided with its own protection cut-out fitted with a 2A HRC fuse link.

The indicator lamps shall be rated for 240 volts (+) or (-) 10%, 50Hz operations.

Unless otherwise stated neon indicator lamps shall not be used.

9. Air Circuit Breaker (ACB)

Air circuit breakers (ACB) shall comply fully with IEC 947 and Local Power Authority requirements with a minimum rated short time, defined as 3 seconds unless otherwise stated, withstand current (rms) and the rated current as shown in the drawings.

The minimum rated service short circuit breaking capacity at the rated operational voltage of the ACB shall be 40 KA (rms) or equal to the 3 seconds withstand current whichever is greater. The minimum rated short circuit making capacity shall be 2.2 times the rated service short circuit breaking capacity.

The minimum rated insulation level and rated impulse withstand voltage shall be 1 KV and 8 KV respectively.

The ACB shall be of disconnector circuit breaker type

When 4 pole ACB is specified, the specified ratings and specifications shall apply to all the poles (i.e. full 4th pole).

The heat dissipation of the ACB at the rated current shall be kept to a minimum such that the ambient air temperature within the ACB cubicle of the switchboard shall not exceed 40°C under normal operating conditions.

The ACB shall be tested and certified by A.S.T.A. or K.E.M.A. or other approved testing authority in circuit breakers

The mechanical endurance of the ACB shall be at least 10,000 C-O cycle without maintenance.

Circuit breakers shall be equipped with independent manual stored energy spring (manually charged) operating closing mechanism unless otherwise stated.

The tripping mechanism shall be stable and not capable of being opened by shocks or jerks. The design of the trip coil shall be such that at the instance when the trip coil is energised the trip plunger shall operate immediately.

Overcurrent release shall be of the series (whole current) or current transformer operated, direct acting trip coil type. They shall have an adjustable low setting overcurrent element of approximately inverse time characteristics with a definite minimum time of 0.1 seconds at about 10 times current and an instantaneous high set element.

The overcurrent setting shall be adjustable from 50% to 200% of the coil (for series coil type) or the current transformer primary rating.

In addition, the circuit breakers shall be provided with shunt trip (dependent voltage).

Both electrically and mechanically operated trip-free mechanism shall be provided.

Circuit breakers shall be provided with contacts which will remove the arcing duty from the main contact surfaces. The main contacts shall be arranged to give a double break in each pole. All contacts shall be renewable.

Individual arc chutes shall be provided on each pole of the breaker. These shall be so designed that any arc caused by the opening of the breaker under maximum fault conditions shall be completely contained in the chute and there shall be no possibility of a "Flashover" between phases, or between any phase and neutral or between adjacent earthed metal.

Auxiliary switches, relays and contactors as necessary for the proper operation of the circuit breaker, trip coils, electrical interlocks, alarm indication and "operation status" indication shall be provided. Auxiliary switches shall be of robust, double break design, easily accessible for maintenance, having adequate current ratings to carry the connected loads

The operating mechanisms/carriage/hinged panel shall be interlocked such that it is not possible to withdraw the breaker when the breaker is in the closed position or to close the breaker while the carriage/panel is in any position between 'fully isolated' and 'fully housed'. Provisions, shall be made to operate the breaker for testing/inspection in the fully isolated position.

10. Moulded Case Circuit Breaker (MCCB)

MCCB shall comply with IEC 947 and Local Power Authority requirements. Frame sizes, rated current and rated ultimate breaking capacity (rms) shall be as shown in the drawing.

The rated service breaking capacity of the MCCB shall be equal or greater than 50% of the rated ultimate breaking capacity.

The rated insulation voltage of the MCCB shall be more than 650 volts with a rated impulse withstand voltage of at least 8 KV.

All MCCB shall be of disconnector type with minimum Class II front face insulation.

A moulded slip-on extension handle shall be provided for MCCBs of current rating 400A and above.

Overcurrent release shall be of the thermal-magnetic type with approximately inverse time characteristic for low values of overcurrent. Calibration temperature shall be at 40 degree C. All MCCB with frame sizes 400A and above shall be provided with adjustable magnetic instantaneous trip. The ON, OFF and TRIP positions of the operating handle shall be clearly defined with the TRIP position approximately halfway between the ON and OFF positions. After a trip operation, it shall be necessary to reset the MCCB by first moving the handle towards the OFF position to engage a latching bar before the breaker can be switched on again. It shall not be possible to prevent the automatic trip action from operating by maintaining the operating handle in the 'ON' position.

The breaker shall be of moulded material with adequate mechanical strength, heat resistant, fire retarding and arc resistant properties to withstand the heat and forces under a fault current appropriate to its interrupting capacity rating. The overcurrent device shall trip all the three phases (through a common trip) to break the three phases simultaneously when operating under overcurrent condition.

Contacts shall be of material with minimum contact resistance, and shall possess maximum freedom from arcing. Arc extinguishing device shall be provided for each phase and shall comprise of magnetic plates mounted on insulating frames. Each pole of the breaker shall be isolated by an integral insulating barrier in the moulded case.

The current rating of the MCCB shall not be affected by the mounting position.

Self locking terminals for connection to external cable shall be provided for efficient and easy application.

The terminals shall apply and maintain a constant and suitable pressure evenly spread over the entire cable ends. Terminals which result in point pressure at the cable ends shall not be used.

The contact resistance of the terminations shall be kept at a minimum at all times.

MCCB's shall have an electrical and mechanical endurance life of not less than 5000 operations with a make and break frequency of not less than 100 operations per hour. Three phase MCCB's shall be rated to operate at voltage and frequency as indicated on the drawings. Tripping devices shall not be affected by a frequency of up to several times the rated frequency.

MCCB's rated for A.C. use shall not be used on D.C. circuits and vice versa. It shall not be allowed to mechanically connect three single phase units by means of an external link bar across the operating handles for use as a three phase unit.

Where specified, MCCB's shall be suitable for mounting of trip coils internally for remote control.

MCCB's shall be mounted in a vertical position with the incoming supply terminals at the top and the load terminals at the bottom.

11. Miniature Circuit Breaker (MCB)

MCB shall comply with IEC 898 and Local Power Authority requirements. The rated current, the rated breaking capacity and the type of thermal magnetic curve shall be as indicated in the drawings.

The overcurrent release shall be of the thermal magnetic type with approximately inverse time characteristic for low values of overcurrent and the following magnetic trip threshold:

Curve B - 3 to 5 times the rated current.

Curve C - 5 to 10 times the rated current.

Curve D - 10 to 20 times the rated current.

The calibration temperature shall be at 40°C.

Positive contact indicator shall be provided.

The ON, OFF and TRIP positions of the operating handle shall be clearly defined with the TRIP position approximately halfway between the ON and OFF positions. After a trip operation, it shall be necessary to reset the MCCB by first moving the handle towards the OFF position to engage a latching bar before the breaker can be switched on again. It shall not be possible to prevent the

automatic trip action from operating by maintaining the operating handle in the "ON" position.

When used as the power supply company's meter cut-off, the MCB shall be provided with an approved means of pad locking the MCB at OFF position.

All MCB at the upstream of all RCCB within the same distribution board shall be provided with sealable cable terminal covers.

The MCB shall be of moulded material with adequate mechanical strength, heat resistant, fire retarding and arc resistant properties to withstand the heat and forces under a fault current appropriate to its interrupting capacity rating. The overcurrent device shall trip all the phases (through a common trip) to break the phases simultaneously when operating under overcurrent condition.

Contacts shall be of material with minimum contact resistance, and shall possess maximum freedom from arcing. Arc extinguishing device shall be provided for each phase. Each pole of the MCB shall be isolated by an integral insulating barrier in the moulded case.

The current rating of the MCB shall not be affected by the mounting position.

Self locking terminals for connection to external cable shall be provided for efficient and easy application.

The terminals shall apply and maintain a constant and suitable pressure evenly spread over the entire cable ends. Terminals which result in point pressure at the cable ends shall not be used.

The contact resistance of the terminations shall be kept at a minimum at all times.

MCB shall have an electrical and mechanical endurance life of not less than 5000 operations. Three phase MCB shall be rated to operate at voltage and frequency as indicated on the drawings. Tripping devices shall not be affected by a frequency of up to several times the rated frequency.

MCB rated for A.C. use shall not be used on D.C. circuits and vice versa. It shall not be allowed to mechanically connect three single phase units by means of an external link bar across the operating handles for use as a three phase unit.

Where specified, MCB shall be suitable for mounting of trip coils for remote control.

MCB shall be mounted in a vertical position with the incoming supply terminals at the top and the load terminals at the bottom.

12. Isolators

Isolators shall be the on-load type. All boards shall have an isolator on the incoming supply for the equipment. For equipment located remote from the board, additional isolators shall be installed adjacent to or preferably within the equipment housing. Exposed isolators shall be heavy duty weatherproof type.

13. Contactors

Contactors shall comply with BS775 ratings mechanical duty Class II and making and breaking category AC3.

All contactors shall be sized for 3 million operations at rated motor load.

Contacts shall be renewable butt-type solid copper hard silver faced, fully shrouded and the design shall be such as to ensure effective freedom from contact bounce and sticking of the fixed and moving positions of the magnet assembly.

Contactor's magnetic coils shall be fully tropicalised and wound for continuous operation at phase voltage +15% with Class "B" insulation to BS2613.

Magnets shall be fabricated from silicon alloy riveted electrical steel sheet with haded pole and magnet/armature assemblies shall be fully floating and self-aligning.

No audible humming noise shall be heard from the contactor at all times.

Arc chutes and magnetic blowout coils shall be fitted to the larger sizes as necessary.

14. Earth Fault and Overcurrent Protection

Overcurrent protection shall be afforded by a 3 elements inverse or very inverse type IDMTL relay as specified and to suit Local Power Authority's requirements.

Earth fault protection shall be afforded by a DTL relay as specified and to suit Local Power Authority's requirement.

The current setting range of the earth fault relay shall be 0.1 to 2A with an adjustable delay time range of 0 to 1 second.

Overcurrent relay shall be provided with adjustable current setting range of 50 - 200% in 25% steps.

The relay shall have low transient overreach and shall be fully tropicalised and shall be in accordance with BS 142. Relays shall be contained in dust proof cases and mounted on the switchboard in a balanced and approved manner.

They shall be of flush mounted draw out pattern type and shall be arranged so that replacements can be effected quickly and with the minimum amount of labour.

All relay circuits shall be capable of breaking or making the maximum current that can occur for which they have to control and they shall not be affected by vibration or by external magnetic field.

Relay contacts shall be of silver, platinum or other approved material and shall be capable of repeated operation without deterioration.

All relays which are connected to complete either the tripping circuits of a circuit breaker or the coil of an auxiliary tripping relay shall be provided with approved indicators which shall be of the mechanically flag or electronically operated type. Indicators shall also be provided on such additional relay elements as will enable the type or phase of the fault condition to be identified. Each indicator of the hand reset type shall be capable of having reset without the necessity of opening the case. Each indicator shall be so designed that it cannot move before the relay has completed its operation.

Permanent facilities shall be provided for testing protective equipment in - situ without having to remove any relay circuits. It shall not be possible to operate any relay by hand without opening the case.

All relays shall be suitably marked with the following information:

Function of the relay

Phase colour of the current supply

Characteristic curve

Rated current and/or voltage of the relay coils

Rated making capacity of tripping contacts or circuits.

All relays shall be capable of withstanding the maximum prospective fault current for a minimum duration of 1.2 times the maximum fault cleaning time including circuit breaker tripping time.

For chiller motors, thermal-magnetic overload protection device shall be provided. The thermal-magnetic overload protection device shall be of adjustable type to suit the equipment rating and starting characteristics.

15. Terminal Blocks for Control Wiring

Terminal blocks shall be mounted on DIN 35 “OMEGA” rails with partitions, end plates and end brackets provided as necessary. The terminal blocks shall be rated at no less than 500V and 20A and shall be interruptible. The connectors shall be suitable for both flexible and solid wires and designed to ensure good electrical connection.

Markers shall be provided on both sides of the terminal block to uniquely identify each terminal block and wire.

16. Earthing

All trifucating boxes, auxiliary wiring connector boxes and switches shall be effectively bonded to earth to comply with local power authority and Singapore Standard CP 16:1991.

The subcontractor shall supply and install a main earth bar of Hard Drawn High Conductivity copper with cross sectional area 37mm x 6mm to which all earthing connections shall be made. This earth bar shall run along the full length of all the main switchboard. This earthing bar should be connected to the main earth point of the earthing system in the form of a ring circuit by means of 25mm x 3.0mm copper tape.

Door panels shall be effectively earthed to the fixed metal frame by means of braided copper straps.

17. Drawings

A drawing showing the type, arrangement, actual dimensions and assembly of the switchboard shall be submitted to the Engineer for approval prior to fabrication and installation.

A neat "AS BUILT" drawing showing the schematic wiring diagram of the switchboard arrangement shall be supplied and framed behind glass by the switchboard manufacturer to be displayed in the main switch room. Drawings shall be permanent A1 size.

18. Labels

Labels of approved pattern and design shall be fitted on the front panels to indicate the service of each switchgear and equipment. Labels shall be of white plastic engraved with black figures or letters and fixed to the panel with brass screws. Labels shall also be provided to identify all items of equipment, circuits, cables and where applicable current rating of fuses and setting of relays.

19. Testing and Commissioning

Testing of the switchboard and certifying that it is safe before supply is energised, and that all the equipment complies with the requirements of this specification shall be done. Generally such tests shall include:

Demonstration that all equipment is installed and all wiring connected so that the board functions as required.

Tests of accuracy of all measuring instruments.

Continuity, phasing out and insulating resistance testing. In general, the insulation resistance of sub-mains feeders and final circuits shall not be less than 50 mega-ohm when tested with a 500V megger.

Protective equipment testing.

Copies of test sheets, showing the results of all tests carried out shall be submitted to the Engineer.

Power Supply Company or local power authority tests on all equipment of the switchboard shall be performed prior to the connection of supply. Arrange for early testing of the switchboard immediately after it is completed. All fees in connection with the required tests shall be deemed to be included in the Tender Price.

21. PVC, PVC/SWA/PVC, PVC/PVC Cables

Single core PVC, PVC/PVC cables shall comply with SS358, IEC227, IEC228, IEC228A, IEC811 and IEC885 with voltage grade of 450/750V.

Multi core cables shall comply with BS6346 with voltage grade of 600/1000V.

High conductivity copper conductors shall comply with SS291, IEC228, and BS6360 in respect of dimension and resistances. Where shaped conductors are used, they shall be compacted to reduce dimensions and to give a smoother profile. Sizes shall be designated by the nominal cross-sectional area.

Where necessary, PVC fillers shall be used between laid-up wires. In the case of cables with extruded bedding, the cores shall be bound with a non-hygroscopic tape before the bedding is extruded.

For twin and multi-core cables the bedding shall consist of two or more layers of PVC tape. For cables with circular conductors, the bedding shall be an extruded layer of PVC.

For armoured cables, the armour shall consist of a single layer of galvanised steel wire or tape as specified. Armouring for single core cables shall consist of non- magnetic material.

The cable shall be finished in an extruded black or grey PVC oversheath, the thickness of which shall comply with BS6346, SS358, IEC227 as appropriate. The external surface of the oversheath shall be embossed with the voltage designation and the manufacturer's name.

Corrosion resistant outdoor type cable glands of the appropriate size shall be used where cables enter or exit from a switchboard/DB and/or where required. Glands shall comply with BS 6121 with integral earth facility. The termination of armoured cable shall be in accordance to manufacturer's recommendation and/or to the Engineer's approval.

The sizing of the cable gland shall be based on the nominal dimension of the cable.

Proper compression cable lugs shall be used for terminating the cable cores onto terminals of devices and equipment.

The cores of the cables shall be identified as follows:

Three Core (three phase) - Red, Yellow, Blue

Four Core (three phase) - Red, Yellow, Blue, Black

Auxiliary cable shall be white with black numbers printed on the cores, commencing 1, 2, 3, 4 upwards.

Cross-Linked Polyethylene (XLPE) Cables

Cross-linked polyethylene (XLPE) cables shall be of 600/1000V grade and shall be stranded copper conductor, cross-linked polyethylene insulated, PVC inner sheathed with galvanised steel-wire armour (as required) and PVC over sheathed power cables. All cables shall comply with IEC 228, IEC 228A, IEC 811 and IEC 885.

The current carrying capacity and the short circuit final temperature of the cable shall comply with IEC 287 and IEC 724 respectively.

Conductors shall be Class 2 annealed compacted stranded plain copper. Insulation shall be cross-linked polyethylene (XLPE) with a high degree of cross linking, free from contaminants and air voids, good heat resistance and it shall be applied by an extrusion process. The XLPE insulation shall be suitable for use in wet and dry locations at conductor temperatures not exceeding 90 deg. C for normal operation, 130 deg. C for emergency overload condition and 250 deg. C for short circuit conditions (5 seconds max. duration).

The cores shall be identified by using the colours RED, YELLOW, BLUE, BLACK for multi core cables.

Non hygroscopic fillers and bedding may be used as required.

The PVC inner (if required) and outer sheaths shall be by an extrusion process. The outer sheath shall be treated so as to be termite proof. The armour (if required) shall be of galvanised steel round wires of diameter 2.5mm.

Fire Resistant Cable

Fire resistant cable shall comply with SS299, IEC331, BS6387 category C, W, Z and IEC332-3 category A or B and shall be of voltage grade 600/1000 volts.

The fire resistant cable shall be of multi-stranded copper conductor type with glass mica flame barrier and cross linked insulation and sheath.

The insulation and sheath material used shall be halogen free with self extinguishing, flame retardant and low smoke emission properties.

The glass mica flame barrier used shall be able to maintain the circuit integrity at the rated cable voltage up to the melting point of the copper conductor.

The insulation and sheath shall be suitable for continuous operation at a temperature of 90°C.

Fire resistant cable shall be strapped or tied to the cable support system as specified in the drawing using stainless steel cable ties or stainless steel strappings.

The stainless steel material shall be of type 304 or better.

The stainless steel cable ties and strap shall be tested and approved for used in fire resistant wiring systems.

The spacings of the straps/ties shall conform to the manufacturers recommendation but shall in all cases not exceed 1m interval.

As far as possible, joints in fire resistance cable shall be avoided. Where this is not possible due to extra long run, prior written approval from the Engineer shall be obtained. When permitted by the Engineer, the joint shall be carried out using method and material recommended by the manufacturers.

The joint method and material used shall not undermine the fire, mechanical and electrical integrity of the cable under all circumstances and are subjected to the Engineer's approval.

All relevant test certificates on the fire resistance cables and support system/accessories shall be submitted to the Engineer for approval prior to ordering of the cable.

22. Cable Trunking/Conduits/Trays/Ladders

1 Cable Trunking

Cable trunking shall be factory epoxy powder coated and shall comply with SS249 and/or IEC 1084. Cable trunking may be employed in place of conduit where multiple runs would otherwise occur.

Trunking shall be of the PSB approved type. The trunking shall be manufactured from good quality electro-galvanised mild steel sheet. Thickness of the trunking shall be in accordance to SS249 recommendation.

The trunking shall be completed as required with factory prefabricated standard bolted flanged outlets, blank ends, reducers, outlet bushes, bends, tees, sleeve couplings, intersection 4-way boxes and fitting adaptors, all of which shall be proprietary-made.

Trunking shall be supported adequately by suitable galvanised steel brackets and hangers spaced not more than 1 metre apart for both vertical and horizontal runs. Vertical trunkings shall be provided with suspension units and thrust blocks. Trunkings shall be supplied in lengths to suit the installation and joints

and bends shall be so constructed that cables can be conveniently drawn through without damaging the cable insulation.

Cables for mains voltage and lighting circuits and extra low voltage systems shall not run in the same trunkings unless they are segregated effectively by means of a rigidly fixed metal barrier or screen.

Trunking runs shall be erected completely before any cable is drawn in and the number of cables installed shall be such that a space factor of 45% is not exceeded.

In vertical trunking runs, insulated type cable support pins and retaining clips shall be fitted to support the weights of the cables. Where conduit is tapped-off trunking, suitable brass bushes shall be fitted at all conduit-entry positions.

All cut edges of the cable trunking shall be treated with anti-rust primer and 2 coats of epoxy paints of minimum thickness 45 microns.

Standard factory made fittings shall be used to form all tees, off-sets, joints and terminations.

The cable trunking shall be earthed at the ends of the run using earthing cables or straps of size equal to the largest earth continuity conductor that is being laid in the trunking.

Copper earthing straps shall be installed across all joints.

2 Conduits

*** OPTIONS ***

Galvanised Conduits

All conduits shall comply with BS 31 and/or IEC 614, IEC 423. All conduit fittings and components shall comply with BS 4568 and/or IEC 1035.

Conduit shall be galvanised, screwed and of welded type class 'B' and fittings shall be manufactured from steel.

Unless otherwise stated, conduit runs shall be concealed in walls, floors and where shown in the drawings. Any request for a waiver must be put in writing to the Engineer for approval.

Concealed conduits shall as far as possible be run in advance, before casting of floor slabs, plastering of walls and casting of columns and beams. The subcontractor shall liaise with the Main Contractor in scheduling this work.

All conduit and accessories shall be painted with one coat of zinc rich paint whenever the exposed galvanised surface has been cut or otherwise damaged, including all exposed threads and connections after erection.

Conduits shall be properly and tightly screwed into the full depth of box spouts and butted in sockets between lengths to ensure maximum mechanical strength and electrical continuity so that the wiring is continuously protected throughout its whole length, and is not in anyway under mechanical stress.

A separate circuit protective conductor of appropriate size corresponding to the maximum current carrying conductor and in accordance with Singapore Standard CP5 shall be provided in all metal conduits. All conduits shall be effectively earthed at terminations.

Conduit sizes shall be selected for the numbers and sizes of cables they are to contain. Conduit size shall not in any circumstances be smaller than 20mm (3/4 inch) and cables drawn in shall not be greater than the appropriate number permitted in Singapore Standard CP5. Conduit shall be arranged with an adequate number of boxes, accessible for the life of the installation so as to allow easy draw in or draw out of any cables later.

Cables for mains voltage circuits and extra low voltage shall not be drawn into the same conduits. A number of final circuits may be grouped together in larger conduits provided that all final circuits in one conduit are of the same phase. In the case of 3 phase circuits all phase wires and neutral, if any should be drawn into the same conduits.

Where condensation is likely to occur in surface conduits they shall be laid with falls so as to drain off condensed moisture without entry into terminations.

The inside surface of all conduits and fittings used in connections therewith shall be smooth and free from signs of corrosions, burrs or other defects. The ends of conduits shall be cut square, filed and reamed out after die threaded or tapped.

All corners shall be turned by easy bends or sets made cold on bending machines without deformation on the conduits or opening of seams. The inner radius of any bend shall not be less than 2.5 times the outside diameter of the conduit. Where it is impracticable to set the conduits, inspection elbows shall be permitted but in no circumstances shall solid elbows or tees be used.

All switches, socket outlets, accessories and other fittings shall be mounted in conduit boxes of suitable sizes. Every conduit box shall be provided with its individual concealed (vertical) conduit dropper. No looping of boxes shall be allowed. Where conduits terminate at a metal base, distribution board, adaptor box, motor starter terminal box or other fittings not designed to accept screwed conduit entry, a socket shall be screwed to the end of the conduit and a smooth bore brass bush/gromet butted together against the inside of the case. PVC bushes will not be permitted.

Where looping pattern boxes are used for outlets, etc. they shall be of circular pattern with an appropriate number of back outlets. Conduits shall be terminated in these boxes by means of screwed sockets and male brass bushes. Ceiling boxes shall be of standard circular pattern with long internally

tapped spouts. All boxes shall be fixed securely to walls, ceilings, etc., by means of at least 2 screws correctly spaced.

Conduit terminations to apparatus including light fittings, detectors, etc. or subject to vibration or movement and installed indoor shall be made in heavy gauge metallic conduit and seated into heavy brass adaptors for connection to the rigid conduit system or apparatus termination boxes.

Where terminations to apparatus subject to vibration or movement and installed outdoor shall be made in PVC sheathed flexible metallic heavy gauge conduit and seated into PVC sheathed heavy brass adaptors for connection to the rigid conduit system or apparatus termination boxes.

The PVC flexible conduits in its natural form shall be heavy duty type, shall have a minimum of 3 ribs per centimetre (cm). The ribs shall be minimum thickness of 3mm and the ribs shall not be spaced more than 2mm apart. The thickness of the PVC material in-between ribs shall not be less than 1mm.

In all cases, the length of the flexible conduit shall be limited to not more than one metre.

All conduit runs shall be straight and run either horizontally or vertically. Diagonal runs will not be permitted. Conduit work and accessories where not concealed shall be fixed effectively by means of heavy pattern spacing full saddles to hold off the conduit from the surface and approved metal plugs and fastenings shall be used. On straight runs the conduit shall be supported by saddles at interval not exceeding 1 metre in addition to supports provided by any structure, box or fittings included in the run. Bends must in all cases be supported on each side by two saddles as near thereto as possible and a draw-in box shall be provided after 2 bends or after not more than each 8 metres of straight run. The subcontractor shall plan the conduit runs such that they are neat and systematic.

On completion of the installation, the subcontractor shall paint all exposed conduit to match the walls, if and where instructed by the Engineer.

*** OPTIONS ***

<u>uPVC Conduits</u>

uPVC round conduits shall be permitted for concealed conduit installations only.

All uPVC conduits used shall comply with BS 4607 & BS 6099 and shall be of high impact, heavy gauge type with nominal wall thickness of at least 1.8mm and minimum diameter of 20mm.

As far as possible, only standard and proper bend fittings shall be used. Where this is not possible, proper bending springs shall be used to form the required bending radius. The bending radius shall under no circumstances be lesser than the bending radius of a standard bend fitting.

Proper uPVC boxes shall be used. All boxes shall be complete with cover and shall comply with BS 4662 and BS 1363.

Proper water resistant adhesive shall be used. The entire uPVC conduit installation shall be adequately supported and fastened before it is concealed.

Proper uPVC pipes cutter shall be used to ensure that no swarf is formed.

3 Cable Trays

Cable trays shall be of the perforated type and constructed of minimum 1.2mm thick galvanised mild steel for width up to and including 75mm and not less than 1.6mm thick for width up to 300mm and not less than 2.0mm thick for larger width. Trays shall be supported at not more than 1 metre intervals by galvanised steel hangers and rods fixed to walls, floors or ceiling in an approved manner. The subcontractor shall ensure that the maximum sag between brackets will not exceed 20mm. Otherwise additional brackets shall be provided. All brackets shall be galvanised. The width of the cable tray shall be such as to allow the cables to be run evenly spaced without overlapping and with spare room to accommodate 30% future increase in number of cables. Shop drawings are to include appropriate sections through each run of tray to show that this is complied with.

All cable trays shall be factory coated with an approved-type epoxy powder of chosen colour and minimum thickness 45 microns prior to installation.

All cut edges of the tray shall be primed with anti-rust primer and finished with 2 coats of an approved-type orange colour epoxy paint of minimum film thickness of 45 microns per coat.

The tray shall be earthed at the ends of the run using earthing cables or straps of size equal to the largest earth continuity conductor that is being laid on the tray.

Copper earthing straps shall be installed across all joints.

The subcontractor shall plan the cable tray route with a view in affording a neat and systematic array and he shall seek the prior approval of the Engineer before commencing the work.

Cables fixed on to the cable tray shall be clipped on with approved type of saddle with galvanised nuts and bolts and/or approved cable tie fastener. Three phase circuits using single core cables shall be bunched with the neutral and secured as a group. Saddles shall not be spaced at more than 750mm apart.

4 Cable Ladder

Cable ladder shall be manufactured from high quality galvanised mild steel and finished with epoxy powder coating of orange colour. The thickness of mild steel used for both rungs and side rails shall be not less than 1.6mm thick for width up to 450mm and 2.0mm thick for bigger width. The depth of side rail shall be not less than 1.5 times the overall diameter of the biggest cable fixed on to the cable ladder. Generally, the rung spacing shall not be more than 300mm in straight runs.

Cable ladder shall be completed as required with prefabricated reducers, elbows, tees, crosses, splice plates, louvered covers and end closers so as to form a complete installation. Cable ladder installed horizontally shall be adequately supported at not more than 0.75 metre interval by galvanised mild steel C-channel and rods fixed to ceiling in an approved manner. For vertical runs, hold down clamps shall be used to secure cable ladder walls at not more than 0.5 metre interval. The ends of the cable ladder run shall be earthed to the system earth by means of earthing cable of size equal to the largest earth continuity conductor that is being laid on the ladder. Copper grounding straps shall be used to improve earth continuity across splice joints.

Cable fixed on to the cable ladder shall be clipped on with approved type of cable tie or with galvanised bolts and nuts. Three phase circuits using single-core cables shall be bunched intrefoil with the neutral and secured as a group. Saddles shall not be spaced at more than 600mm apart.

Motors

All motors shall comply with BS5000 and shall be continuously rated. They shall have Class B insulation to BS2757. They shall be suitable for operation at ambient temperatures up to 45 deg. C. Motors shall be of the totally enclosed fan-cooled type.

Motors shall be sized for a non-overloading rating throughout the full range of operating points for the driven load. They should be capable of accelerating the driven load to full speed within the following times and starting currents:

Direct-on-line:

Maximum starting current 6 times full load current and maximum starting time 5 seconds.

Star Delta and Other Forms of Starting:

Maximum starting current 2 times full load current and maximum starting time 10 seconds.

Electronic Soft Starter

Maximum starting current 3 times full load current and maximum starting time 1 second.

All motors above 30kW in rating shall have a full load efficiency greater than 92% and a power factor greater than 0.90. All motors above 3kW in rating shall have a full load efficiency greater than 87% and a power factor greater than 0.85.

Motors of over 700W rating shall be 3 phase and motors up to 700W may be 1 phase.

Motors shall be capable of operating continuously at rated output at any frequency within 2Hz of nominal frequency and at any voltage within 10% of nominal voltage.

Motors of rating 3kW and above shall be provided with six terminals for the windings. Motors smaller than 3kW may have 3 terminals. Separate earthing terminals shall be fitted. Terminal boxes shall be of adequate size for the easy termination of supply cables. Terminal boxes shall be weatherproof.

Motors shall be vibration free. They shall be securely mounted onto the driven equipment or onto a common bedplate with the drive equipment. Properly selected vibration isolators shall be provided for the equipment to prevent transmission of vibration to the structure that supports them.

Where variable speed drives are required to control motor speed, the subcontractor shall obtain written confirmation from the motor manufacturer that the motor is suitable for the duty intended. No additional cost will be entertained due to the tenderers failure to comply with this requirement.

Motors shall be fitted with bearings with a design life of 100,000 hours. The tenderer shall submit confirmation of this with his tender.

Motor Starters

Unless otherwise stated starters for all equipment shall be mounted in the control board which controls that equipment. Starters for equipment for which the starter circuits are not shown in the Drawings shall be supplied complete with starters which are standard components of the equipment manufacturer.

Starters shall be rated for 60 start/stop per hour or to the intended duty for the motor/equipment supplied whichever is greater.

The type of starter shall be as follows except where variable speed drives are required:

Methods of starting motors shall be as follows:

Less than 3kW	-	Direct-on-line
3kW to 30kW	-	Star Delta
Above 30kW	-	Close Transition Auto Transformer with minimum 3 steps

Electronic soft starters shall be modular in design, factory prewired ready for installation into control panels. Functions shall be available for adjusting/limiting motor starting current, adjusting acceleration and deceleration time start-up boost pulse, and shall be complete with LED indication of fault, overload and fault, in built cooling fan and power supply transformers. Starter shall be suitable for the application intended.

Electronic soft start starters c/w appropriate filter and shall be suitable for operation with an input voltage variation of +15% of the nominal supply voltage and an ambient of up to 400C and it shall be rated at least 60 starts/stops per hour. Once the motor has reached synchronism speed, the control system shall automatically switch out of circuit.

Resistors, inductors, and auto transformers used in the closed transition star-delta starters and auto-transformer starter respectively shall be adequately rated to sustain the motor starting current for minimum of 2 times the starting time and shall be protected against over-heating by means of a suitable sensor and cut off device.

Where resistors are used it shall under no circumstances that the surface temperature of the resistor exceed 50°C. All wiring connections to the resistors shall only be made in fire resistant cables.

The auto-transformers starter shall be provided with sufficient number of steps at appropriate tapping such that it will provide a smooth start-up of the motor with starting current not exceeding 2 times the motor full load current at all times and a maximum starting time of not more than 10 seconds. In any case, the minimum number of steps shall be 3.

All starters shall be equipped with the appropriate overload protection device.

23. VARIABLE SPEED DRIVES

Variable speed drives shall be of the high efficiency, low maintenance, ac adjustable frequency type employing the principle of Pulse Width Modulation (PWM) design. Direct current drives, eddy current belt drives, hydraulic drives and any other drives shall not be acceptable.

The variable speed drive shall meet the following minimum specifications as listed below:

1.	Oput Rated Voltage	:	Selectable (415V, 3 Phase)
2.	Input Voltage Tolerance	:	+10% to -15% of Rated Voltage
3.	Input Frequency	:	50 Hz
1.	Output Frequency	:	Selectable (1-50 to 100 Hz)
2.	Frequency Stability	:	175 parts per million/°C
3.	Acceleration/Deceleration	:	Continuously adjustable from 0.75 to 150 sec.

4.	Speed Input Signals	:	Can be any of the following: - 0 to 10V dc - 1 to 5V dc - 4 to 20mA dc
5.	Input Rated Voltage	:	Selectable (415V, 3 Phase)
6.	Input Voltage Tolerance	:	+10% to -15% of Rated Voltage
7.	Input Frequency	:	50 Hz
8.	Output Frequency	:	Selectable (1-50 to 100 Hz)
9.	Frequency Stability	:	175 parts per million/°C
10.	Acceleration/Deceleration	:	Continuously adjustable from 0.75 to 150 sec.
11.	Speed Input Signals	:	Can be any of the following: - 0 to 10V dc - 1 to 5V dc - 4 to 20mA dc
12.	Input Rated Voltage	:	Selectable (415V, 3 Phase)
13	Input Voltage Tolerance	:	+10% to -15% of Rated Voltage
14.	Input Frequency	:	50 Hz
15.	Output Frequency	:	Selectable (1-50 to 100 Hz)
16.	Frequency Stability	:	175 parts per million/°C
17.	Acceleration/Deceleration	:	Continuously adjustable from 0.75 to 150 sec.

18. Speed Input Signals : Can be any of the following:

- 0 to 10V dc
- 1 to 5V dc
- 4 to 20mA dc

and shall be able to accept any form of differential or earth referenced speed signal from a standard transducer.

12. Fault Protective Circuits

The drive shall trip without any damage to its components when any of the faults described below happens. Each fault shall be identified by its own distinct LED indication. The drive shall be able to re-start after system reset.

Earth Fault

When a phase to earth short-circuit appears on any or all phases.

Short Circuit Fault

When a phase to phase short-circuit appears on any or all phases.

Overcurrent Fault

When the output or regenerative current exceeds the maximum current rating of the drive.

Undervoltage Fault

When the input voltage falls below -15% of the rated input voltage or if there is a loss of one or more phases.

Overvoltage Fault

When the input voltage exceeds +10% of the rated input voltage or if the regenerative voltage exceeds the internal DC bus voltage of 720 V dc.

Over Temperature Fault

When the temperature of the internal heat sink rises above 80°C.

13. In addition to the above protective circuits, the drive shall also be provided with the following protections.

Line Transients.

Insensitive to incoming power phase sequence.

Current Limiting: 55 - 110% adjustable for maximum output current.

Remote Trip

An external motor overload device or a smoke detector may be connected to trip the drive when the contact of the overload device/smoke detector opens. A Remote Trip LED shall be lit.

10. Stalling Prevention

The drive shall be designed with Acceleration and Deceleration Limit Circuit to avoid nuisance tripping when:

The starting current drawn is too high or the acceleration time set is to fast.

The regenerative voltage is too high or the deceleration time set is too fast.

12. Start Boost

Switch adjustable from Low, Normal, Medium or High to provide different Volt/Hertz profiles (motor starting torque) at low speeds to suit different applications. A 0 to 100% Boost potentiometer shall be provided to give fine adjustment for each Boost Selection.

13. Flux Compensation

Shall provide energy savings by automatically reducing the motor flux whenever the motor is not fully loaded, especially when the motor has been "oversized" for the load it is required to drive. Motor heating is also reduced. Very suitable for variable load application like VAV system.

14. Slip Compensation

Automatically adjusts output frequency and voltage as motor speed changes due to load variation. Provides improved speed regulation with large changes in motor load.

15. Ambient Temperature Range

Operating = 0 to 50°C.

16. The variable speed drive shall be the panel mount type and provided with the following features:

LED status indication showing the operational condition of the drive like:

- Power "ON"
- Zero speed
- Enabled
- Forward or Reverse mode

- Faults, e.g. Earth Fault, Overcurrent, Over Regenerative Current

Under Voltage, Over Voltage, Over Temperature, Remote Trip

Forward and Reverse Selector

Run and Stop Switch

Auto and manual speed selector

Remote and local mode selector

17. Digital speed meter able to be calibrated to read 0 - 100% speed. The variable speed drive shall have the capability, if required, to connect a load meter (digital or analogue) to read the loading of the drive.

18. The variable speed drive shall be able to automatically restart itself after a fault has caused it to shut down. A minimum of five consecutive restart attempts shall be provided. If the fault persists after the fifth attempt, the drive shall shut down and cause the FAULT relay to energise. A manual reset is necessary after the removal of the fault.

19. The variable speed drive shall be complete with anti-harmonics line filters to prevent harmonics current and voltage generated by the drive set from being injected back into the mains supply.

The limit of the harmonic distortions caused by the variable speed drive to the supply line shall not exceed the following at all times.

Harmonic Voltage Distortion

	Max. Allowable Individual Harmonic Voltage Distortion Up To The 19th Harmonic
Odd Harmonics	2%
Even Harmonics	1%

The allowable total harmonic voltage distortion shall not be more than 5%.

Harmonic Current Distortion

	Max. Allowable Individual Harmonic Current Distortion Up To The 19th Harmonic
Odd Harmonics	6%
Even Harmonics	4%

The allowable total harmonic current distortion shall not be more than 10%.

The filter shall be capable of withstanding 150% of the variable speed drive rated input current.

The Subcontractor shall verify that the limits of the harmonics distortions to the supply line is not exceeded on site in the presence of the Engineer using an approved type of spectrum analyser.

Fire Command Centre Interface

Provide all detailed drawings for mimic panels and control panels required for the FCC to the main contractor who shall coordinate the works.

Once coordinated, complete all works in the FCC expeditiously and not later than 6 weeks prior to FSB/RI TFP testing. All control works for the systems described above shall be hardwired and included in this contract, and no delays to the completion of the works in accordance with the above shall be entertained.

Particular attention shall be given to verifying all interlocking, control and mimic indication is correctly done in accordance with this specification and the local authority requirement