Table of Contents

TECHNICAL SPECIFICATIONS

2. AIR HANDLING UNITS

2.1 Scope

Thescope of this section, comprises thesupply,erection, testingand commissioning of double skin construction "EUROVENT CERTIFIED"air handlingunits,conforming to these Specificationsandin accordance with requirements of drawings and of theSchedule of Quantities.

2.2 Type

Theair handling units shallbe double skin construction, draw-thru / blow thru type comprising of various sections, filtersection,coil section and fan section, mixing box,(where ever the return air and fresh air are ducted) as shownon drawings and included in schedule of quantities.

2.3 Capacity

Theair handling capacities, maximum motor horsepowerand static pressure shall be as shown on Drawings and in Schedule ofQuantities.

2.4 Casing

Double skinned panels shall be 25mm ± 2mm / 50mm ± 4mm thick made of galvanized steel,pressure injectedwith PU foaminsulation (density40 kg/m^3) with K factor not exceeding 0.02Watt/Mc shall befixed to minimum 1.5 mm thick aluminium alloy twin box section structural Frame work with stainless steel screws.Outer sheet of panels shall be made of galvanised prepainted with PVC guard film sheet of 0.63 mm thick, and inner sheet of 24 Gauge plain G.I. Sheet.

Theentire framework shall be mounted on an aluminium alloy or galvanized steel (depending on size) channel base as per manufacturer's recommendation. The panels shall be sealed to the frame work by heavy duty neoprene gaskets held captive in the framed extrusion.All panels shall be detachable or hinged.Hinges shallbemade of die cast aluminum / hard nylon with stainless steel pivots, handles shall be made of hard nylon and be operational from both inside and outside of the unit.Units supplied with various sections shall be suitable for on-site assembly with continuous neoprenegasket. All fixing andgaskets shall be concealed.

Units shall have hinged, quick opening access door in the fan section and also in filter section where filters are not accessible from outside. Access doors shall be of double skin construction similar to unit.

Condensate drain pan shall be fabricated from 18 gage stainless steel sheet with all cornerswelded. It shallbe isolated from bottom floor panel with 19 mm elastomeric nitrile rubber for ceiling suspended. For floor mounted unit drain pan shall be externally insulated with 19 mm self-adhesive elastomeric nitrile rubber/ XLPE.

Internal panels shall be fabricated so that there are no gaps between the panel and frame work. Fabrication clearances shall be closed with blank-off pieces or with sealant. Partitions shall be of sufficient thickness to prevent deflection and vibration during AHU operation. Manufacturer shall provide suitable stiffening by means of box type members across the same. AHU shall be with clean inside surfaces with beveled corners to the best possible extent without crevices as may allow growth of algae / fungus. In case on internal fittings such as dampers, the same shall be with beveled edges and without sharp corners to prevent operator injury. There shall be no screws projecting into AHU or air stream. If the same is unavoidable, the tips shall be fitted with rubber caps to prevent operator injury.

AHU panels shall be factory fitted with pressure ports for DPT installation. The number and size of these shall be confirmed in the AHU technical approval stage. In case opening is to be made in AHU panel, the same shall be with C-channel all around to prevent entry of PUF into air

stream. The channels shall be cut at 45 degrees at the corners to avoid overlap. Material for the channel shall be same as that of internal skin of AHU.

Rubber grommets shall be provided at all entry points into AHU such as coil connection, cable entry etc. The same shall be double lip tight fitting to prevent air leakage.

All access doors shall be outward opening. For doors provided downstream of the fan, especially in high static AHUs, additional clamps shall be provided along periphery of door to maintain constant pressure and ensure proper sealing.
Water resistance marine light with power cabling shall be included
Micro switch with wiring for Door shall be provided such that fan motor shall stop upon opening the door.

2.5 Mixing Box

AHU'srequiring mixing boxes as specified in Schedule of Quantities shallbe complete with fresh and return air dampers.

2.6 Thermal Break Profile

AHU's such as TFA units, AHU with mixing box having return air ducted shall be provided with thermal break profile as indicated in schedule of quantities. Also these AHU's shall be provided with ~~46~~ 50mm ± 4mm thick panel. Panels and thermal break profiles for all AHUs shall be designed and assembled in such a way that there shall not be any condensation on AHU withconditions of 15^0C and 92% RH (AHU surrounding conditions) at designed operating conditions inside the AHU.

2.7 Damper

Dampers shall be opposed blade type. Blades shall be madeof doubleskinnedairfoil aluminiumsectionswithintegral gasket and assembled within a rigid extruded aluminiumalloy frame.
All linkagesandsupportingspindlesshallbemadeofaluminiumornylon, turning in teflon bushes. Manual dampers shall be provided with a bakelite knob for lockingthe damper bladesinposition. Linkages shallbeextendedwherever specified for motorised operation. Damper framesshallbe sectionalised to minimise blade warping. Air leakagethrough dampers when in the closed position shall not exceed 1.5%of the maximum design air volume flow rate at the maximum design air total pressure.

2.8 Motor and Drive

Fanmotors shall be energy efficient (IE-3) and shall be 415±10% volts,50 cycles, three phase, totallyenclosedfan-cooled classF, with IP-55 protection. Motors shallbeespecially designed for quiet operation and motor speed shall not exceed 1440rpm for forward curved fan and 2900 rpm for backward curved fan. Drive to fan shall be provided throughbelt-drive arrangement. Belts shall be of the oil-resistant type. For three stage filtration AHUs, belt drive shall not be used and direct driven plug fans shall be used.

2.9 Fan

Fansshallbe "AMCA certified" centrifugal, forward curved / backward curved / backward curvedairfoil so as to give maximum efficiency for given duty condition. Fans driven by variable frequency drive shall be backward inclined irrespective of static pressure value.Fans shall be selected for minimum efficiency of65% for forward curved and 75% for backward curved/ airfoil. Fan casingshallbe madeof galvanised steelsheet.Fanwheels shallbemadeofgalvanised steel.Fanshaftshallbe groundedC40- 45carbon steel andsupportedinself-aligning plummerblockoperatingless than 75%offirstcritical speed,greaselubricated bearings. Fan wheelsandpulleys shallbeindividuallytestedandprecisionbalanced dynamically. Fan motor

assembly shall be statically and dynamically balanced to G6.3 grade as per relevant ISO/AMCA standard. Computerized fan selection print outs shall be submitted along with the offer.

Motors shall be mounted inside the AHU casing on sliderails foreasybelttensioning. Motors shall driveheavy duty V-belt, constant pitch, drive selected at minimum 110% ofmotor horsepower.

Bothfan and motors assemblies shall bemounted onadeep sectionaluminiumalloy or galvanised steel(dependingon size) base frame.

Combination spring and rubber anti vibration mounts shall be provided for isolating the unit casing. Flame retardant, waterproof silicone rubber impregnated flexible connection shall be provided at the fan discharge.

2.10 Cooling Coils

Chilledwatercoilsshall have 12.5 to 15mmdia(O.D)tubesminimum0.4 mm thickwith sine wavealuminiumfinsfirmly bonded to copper tubes assembled in stainless steelframe.Faceandsurfaceareas shall be such astoensurerated capacityfromeach unitandsuchthat theairvelocity acrossthe coil shall not exceed 150 meters per minute.(500fpm)The coil shall be pitched in the unit casing for proper drainage. The coil shall have copper header with chilled water supply & return connections protruding out of AHU casing by minimum 150 mm and fitted with dielectric coupling or adapter for connection with MS pipes. Eachcoilshallbe factory-tested at 21 kgpersq. cmair pressureunder water. Tubeshallbehydraulically/ mechanically expanded for minimum thermal contactresistance withfins. Fin spacing shall be 4 - 5 fins per cm. Water pressure drop in coil shall not exceed 10 PSIG(0.70 kg/cm.sq.)

Coils shall be provided with mechanical means to purge air from the coil during commissioning by means of a purge valve or nipple. To prevent splashing, discharge from the same shall be routed to the condensate drain pan by means of flexible PVC tubing of suitable diameter. Purge valve / nipple shall be accessible externally or by removal of blanking panel.

All AHU'sshall be provided with minimum 6 Row Cooling Coil.All TFA AHU's shall be provided with minimum 8 row cooling coil. TFA units which receives pre-cooled fresh air can be provided with 6 row deep coil upon verification of coil selection output.Reheat coil may be provided if indicated in Schedule of Quantities. Reheat coil shall be 2 row deep and shall be of same construction as defined above.

In case AHU has multiple coil stacked one above another, intermediate drain tray of SS 304 (18 gauge) shall be provided so that upper level of coil drains into this drain tray. Copper / SS 304 piping shall be provided from this drain tray upto main bottom tray.

Computerized cooling coil selection output shall be submitted. Coil rating shall be as per AHRI-410 / EUROVENT Certified.

2.11 Filters

Eachunit shall be provided with a factory assembledfilter section containing washable synthetic type air filters having anodisedaluminium frame. The filter shall have minimum 90% efficiency down to 10 microns . The media shall be supportedwith HDPmeshonone side and aluminiummeshonotherside.Filterbanksshall be easily accessibleanddesignedfor easy withdrawal and renewal of filter cells. Filterframework shallbe fully sealed and constructed from aluminiumalloy. For green buildings, AHUs shall also be provided with MERV-13 filters, if the project is opting for credit EQ-5.

2.12 Accessories

Each air handling unit shall be provided with manual air vent athighpointin the cooling coil and drainpluginthe bottomof the coil. In addition, thefollowingaccessories mayberequiredatairhandlingunits,theirdetailed specifications are given in individual sections, & quantities separately identified in schedule of Quantities.

a. Insulatedbutterflyvalves, balancingvalves, `Y' strainer,union & condensate drain piping with 'U' trap upto sumpor floordrain in air handling unit room, as describedin section "Piping".

b. Thermometersin the thermometer wells & pressuregauge (with cocks) within gauge ports in chilled / hot watersupply and return lines as per the section "Instruments".

c. Minimum 2 Nos nameplates (1 in etched metal and other plastic) mounted onto AHU panel with suitable water-resistant adhesive along with relevant warning stickers on various panels. The nameplate shall give all relevant details including fan model selected, motor KW, Air quantity and total static pressure.

2.13 Isolators

Vibrationisolators shall be provided with all airhandling units. Vibration isolators shall be spring isolators. Minimum vibration isolation efficiency shall be 90%.

2.14 Fresh Air Intakes

Extruded aluminium construction dulyanodized (20microns andabove)fresh air louvers with birdscreenand dampers shall be provided in the clearopenings inmasonrywallsof the air handlingunitroomshaving atleastoneexternal wall.Louvers,damper,pre-filters, ductsandfreshairfan with speed regulator shall be provided as shown on Drawings and in Schedule ofQuantities.Fresh air dampers shall be of the interlocking, opposed-blade louvertype.Bladesshall be made of extruded aluminium construction and shallbe rattle-free. Dampers shall be similar to those specified in "Air Distribution". Freshair fansand fresh air intakes shall be as per therequirements of Schedule of Quantities.

2.15 Painting

Shopcoats of paint that have become marred duringshipment orerection shall be cleaned off with mineral spirits,wire brushed and spot primed over the affected areas, thencoated withpainttomatch the finishovertheadjoiningshop painted surface.

2.16 Performance Data

Airhandlingunitshallbeselectedforthelowest operatingnoiseleveli.e not exceeding 65 dbA @ 3 metre distance from theequipment.Fanperformance ratingandpower consumption data, withoperatingpoints clearlyindicatedshall be submitted and verifiedatthe time of testing and commissioning of the installation.

2.17 Testing

Coolingcapacityofvarious air handlingunitmodelsbe computedfrom the measurements of air flow and dryandwet bulbtemperatures of air entering and leaving the coil. Flowmeasurements shall be byananemometerandtemperaturemeasurements by accurately calibratedmercury-in-glass thermometers. Computedresults shall conform to the specified capacities and quoted ratings. Powerconsumption shallbe computed from measurements of incoming voltageand input current.

3 VARIABLE REFRIGERANT FLOW SYSTEM

3.1 Scope

The scope of this section comprises the supply, erection, testing and commissioning of Variable Refrigerant Volume System conforming to these specifications and in accordance with the requirements of Drawings and Schedule of quantities.

3.2 Type

Unit shall be air cooled, variable refrigerant volume air conditioner consisting of one outdoor unit and multiple indoor units.Each indoor unit having capability to cool independently for the requirement of the rooms.

It shall be possible to connect multiple indoor unit on one refrigerant circuit as shown in the drawings or as indicated in schedule of quantities.The indoor units on any circuit can be of different type and also controlled individually. Following type of indoor units shall be connected to the system :

-Ceiling mounted cassette type.
-Ceiling mounted ductable type.
-Wall mounted Hi-Wall type.
-Floor mounted type.

Compressor installed in outdoor unit shall be equipped with capacity control mechanism, and capable of changing the rotating speed / mass flow rate of refrigerant by scroll / rotary compressor RPM to follow variations in cooling.Outdoor unit shall be suitable for mix-match connection of all type of indoor units.

The refrigerant piping between indoor units and out door units shall be extended upto 100m with maximum 50 m level difference without any oil traps. Oil recovery system shall be managed without disturbance to normal operation cycle of the system / compressor.

Both indoor unit and outdoor unit shall be factory assembled, tested and filled with first charge of refrigerant before delivery at site.

3.3 Selection Criteria For Vrf Unit

- The manufacturer to certify that the proposed unit shall be operational un-interrupted at temperature 3°C plus peak ambient dry bulb temperature of design city.

  Manufacturer to submit OEM letter for continuous operational range of the unit.

- Manufacturer to submit OEM de-rating charts for indoor and outdoor unit capacity rating at project specific design conditions and refrigerant piping lift and distance.

- ADP of unit selected should not be lower than 11.11°C (52°F) for high wall units and 10.56°C (51°F) for concealed ductable and cassette units.

3.4 Out Door Unit

The outdoor unit shall be factory assembled, weather proof casing constructed from heavy gauge mild steel panels with powder coated finish.

All outdoor units above 8 HP rating shall have minimum two number scroll / rotarycompressors.

In case of outdoor units with multiple compressor, the operation shall not be disrupted with failure of any compressor.

The noise level shall not be more than 60 dB (A) at normal operation measured horizontally 1m away and 1.5 m above ground level.

The outdoor unit shall be modular in design with possible future expansions.

The unit shall be provided with microprocessor control panel.

3.5 Compressor

The compressor shall be high efficiency scroll / twin rotary type and capable for capacitycontrolling.It shall change the speed / refrigerant mass flow rate in accordance to the variation in cooling load requirement. Refrigerant mass flow rate can be changed by speed modulation of compressor / mechanical control system. System shall incorporate liquid sub-cooling mechanism.

The inverter shall be IGBT (insulated gate bipolar transistor) type for efficient and quiet operation.

All outdoor units shall have multiple steps ofcapacity control to meet load fluctuation and indoor unit individual control.All parts of compressor shall be sufficiently lubricated.Forced lubrication may also be employed.

Oil heater shall be provided in the compressor casing.

3.6 Heat Exchanger

The Heat Exchanger shall be constructed with copper tubes mechanically bonded to aluminium fins to form a cross fan coil and larger surface area.

The fins shall have anticorrosion treatment for Heat Exchanger Coil.The treatment shall be suitable for areas of high pollution, moisture and salt laden air.

The casings, fans, motors etc. shall also be with anti-corrosion treatment asa standard features.

The unit shall be provided with necessary number of direct driven low noise level propeller type fans arranged for vertical / horizontal discharge.Each fan shall have a safety guard.

3.7 Refrigerant Circuit

The Refrigerant Circuit shall include an liquid receiver /accumulator, liquid & gas shut off valves and a solenoid valve.All necessary safety devices shall be provided to ensure the safety operation of the system..

3.8 Safety Devices

All necessary safety devices shall be provided to ensure safe operation of the system.

Following safety devices shall be part of the outdoor unit : high pressure switch, low pressure switch, fuse, crankcase heater, fusible plug, over current protection for inverter, and short recycling guard timer.

3.9 Piping

All connections of Refrigerant piping shall be in high grade Copper of Refrigeration quality with Eddy Current Testing and material test Certificates.

All connections, tees, reducers etc. shall be standard make fittings.

Insulation of cold lines shall be carried out with nitrile rubber insulation sheets and tubes of appropriate thickness so that condensation does not occur.

For individual Piping 50 / 100 mm wide Aluminium Tape shall be used at joints of Piping with Bands for identification.

For outdoor piping, the finish shall be woven GRP Mat finished with coloured Epoxy paints to withstand outside ambient conditions and UV Radiation.

3.10 Oil Recovery System

Unit shall be equipped with an oil recovery system to ensure stable operation with long refrigerant piping.

System shall be designed for proper oil return to compressor along with the distribution of oil to individual compressor.

The refrigerant piping shall be extended upped 100 M with 50-M level difference without oil traps.

3.11 Indoor Units

Units shall be factory assembled, wired, piped and tested.

Units shall have DX coils with copper tubes and bonded aluminium fins for highly efficient heat transfer.

Units shall have Centrifugal fans for adequate amount of Air circulation and low Noise.

Units shall have inlet filters, which are easily cleanable and replaceable.

All components of Units are easily accessible for connection, repairs and maintenance.

Units shall have very low noise.

All units with Factory manufactured Units Grills shall have auto swing feature for proper Air distribution.

All unit shall be controlled by electronic Expansion Valves only.

Allunits mounted inside the ceiling shall have fans capable of sustaining duct connections, and special filters if necessary.

Visible indoor units shall have wireless remotes. Price of the same shall be included in cost of unit by default.

Concealed indoor units shall have sensor mounted on supply air grilles / diffusers which can be controlled with wireless remotes.

Anticorrosion treatment for avoiding corrosion of coils.

All units shall have adequate insulation or Lining to avoid condensation.

Cooling coil and refrigeration parameters shall be designed in such a way that supply air temperature shall not be less than 14^0C or 1^0C above room dew point temp, whichever is more. Contractor shall guarantee inside conditions with selected supply air temperature.

3.12 Ceiling Mounted Cassette Type Unit (Multi-Flow Type)

The unit shall be ceiling mounted type.The unit shall include pre-filter, fan section and DX-coil section. The housing of the unit shall be powder coated galvanised steel. The body shall be light in weight and shall be possible to suspend from four corners.

Unit shall have a external attractive panel for supply and return air.Unit shall have four way supply air grilles on sides and return air grille in centre.

Each unit shall have high lift drain pump, fresh air intake provision (if specified), and very low operating sound.

3.13 Ceiling Mounted Ductable Type Unit

Unit shall be suitable for ceiling mounted type. The unit shall include pre filter, fan section & DX-coil section.The housing of unit shall be light weight powder coated galvanised steel.The unit shall have high static fan for ductable arrangement.

3.14 High Wall Mounted Units

The units shall be high wall mounted type.The unit shall include pre-filter, fan section & DXcoil section.The housing of unit shall be light weight powder coated galvanized steel.

Unit shall have an attractive external casing with supply and return air grills.

3.15 Floor Mounted Units

The unit shall be suitable for floor mounting.The unit shall include, prefilter fan section, DX. Coil section.The housing of unit shall be light weight powder coated galvanised / anodised aluminium panels. Unit shall have an attractive external casing with supply & return air grilles.

3.16 Central Remote Controller (Option If Specified In Boq)

A multi-functional microprocessor based centralized controller (central remote controller) shall be supplied as an optional accessory.

The controller shall be able to control upto minimum 64 nos. of indoor units with zoning option and / or in case of larger installation should provide bigger controller with the following functions.

- Temperature setting for each zone, or group, or indoor unit.
- On/Off as a zone or individual unit.
- Indication of operating condition.
- Select ON of all operation modes for each zone..
- The controller shall have wide screen liquid crystal display and shall be wired by a non polar 2 / 3 wire transmission cable to a distance of 1000m away from the indoor unit.
- The controller shall be integrated to BAS system thru software for monitoring & controlling of all aboveparametersincluding start/ stop of each indoor / out door unit. All necessary interface cards / units should be supplied as a part of the system to integrate to the BASSoftware.

3.17 Unified On/Off Controller (Option If Specified In Boq)

Unified ON / OFF controller shall be supplied as an optional accessory.

The controller shall be able to control minimum 2 groups (each group containing maximum 16 indoor units) or 110 nos. of indoor units with the following functions.

- On / Off as a zone or individual unit.

- Indication of operation condition of each group.
- Select one of 4 operation modes.

The controller shall be wired by a non-polar 2 wire transmission cable to distance of 1 km away from indoor unit.

The controller shall be integrated to BAS system thru software for monitoring & controlling of all aboveparametersincluding start/ stop of each indoor / out door unit. All necessary interface cards / units should be supplied as a part of the system to integrate to the BASSoftware.

3.18 Condensate :

25mm dia uPVC pipes, 40mm dia uPVC headers & fittings shall be used forcondensate, from Evaporator Unit to drain point.The joints shall be properly sealed so that there is no water leakage.U-trap shall be provided at the end.Additional insulation drain tray shall be provided below the Evaporator Unit, if required.

Mounting

All indoor units shall be mounted with Brackets, Hangers etc.with proper size anchor Fasteners.

3.19. Electrical Installation

For Variable Refrigerant flow systems, power will be provided near outdoor unit location. HVAC Contractor to provide suitable distribution panel along with 3-phase power to outdoor units and single phase power to all indoor units fed by these outdoor units. Power / control cabling and earthing along with supports shall be included.

4. FANS

4.1 Inline Fans

4.1.1 Circular Inline Fans

Circular inline Centrifugal duct fan shall be a straight through radial fan. It should be compact.

The fan shall cope with high pressure and long duct runs, whilst still operating at an acceptable sound level.

The circular inline fans should be moisture resistant and should be approved for installing in humi or damp environments. The fans should be rated IP-44 when installed in a duct system. The casing should be manufactured from pre galvanized steel. Automatic thermo – contact shall open up if the temperature within the motor windings becomes excessive. Fan should be equipped with CE certified external rotor single phase asynchronous motor.

4.1.2 Cabinet Inline Fans

The Cabinet of the cabinet inline fans should be manufactured in 20 gauge galvanized steel complete with inlet and outlet spigots. The Mounting brackets and access panel should be fitted as per manufacturer standard. The impeller of the fans should be with high efficiency forward curved DIDW type. The scroll of the fans should be fabricated with galvanized sheet steel. The motor of the fans shall be Squirrel cage induction type with bearings swealed for life. The motor shall be suitable for single phase electrical supply. The cabinet of the fan shall be of double skin construction with 20 gauge GI outer skin with 25 mm glass wool wrapped tissue paper and covered with 20 gauge perforated GI sheet from inside.

4.2 Performance Data

Allfansshall be selected for the lowestoperatingnoise level.Capacityratings, power consumption,withoperating points clearly indicated, shall be submitted and verifiedat the time of testing and commissioning of the installation.

4.3 Testing

Capacityofall fans shall be measuredbyananemometer.Measuredair flow capacities shall conform to thespecified capacitiesandquoted ratings. Power consumptionshallbe computedfrommeasurements of incomingvoltageandinput current.

5. PIPING

5.1 Scope

The scope of this section comprises the supply and laying of pipes,pipe fittings and valves, testing and balancingof all water and refrigerant piping required for the complete installation as shown on the Drawings. All piping inclusive of fittings and valves shall follow theapplicableIndian Standards. All welders used for piping erection shall be well qualified (certificate should be submitted to Project Manager for approval) and shall have minimum 8 to 10 years' experience.

5.2 Pipe Sizes

Pipesizesshall be as required for the individual fluid flows.Various pipesizes have been indicated on the Drawings, these are for Contractor's guidance only and shall not relieve contractor of responsibility for providing smooth noiseless balanced circulation of fluids.

5.3 Refrigerant Piping

a. Allrefrigerant pipes and fittings shall be hard drawn copper tubes and wrought copper / brass fittingssuitable forconnection with silver solder / phos-copper.

b. Alljoints in copper piping shall be sweat jointsusing low temperature brazing and / or silversolder.Before jointing any copper pipe or fittings, its interiors shall bethoroughly cleaned by passing a clean cloth via wire or cable through its entire length. The piping shallbe continuouslykept clean of dirt etc. whileconstructing thejoints. Subsequently, it shall be thoroughly blown out using carbondioxide / nitrogen.

c. Refrigerant lines shall be sized to limit pressure drop between the evaporator and condensing unit to less than 0.2 kg per sq.cm.

d. Sight glass with moisture indicator and removable type combination dryer cum filter with MS housing and brass wire mesh / punched brass sheet shall beinstalled in liquid line of the refrigeration system incorporating a three valve by pass. After ninety days of operation, liquid line drier cartridges shall be replaced.

e. Heat exchanger shall beMS heavy duty pipe in pipe type and without any joint in the inner pipe.

f. Horizontal suction line shall be pitched towards the compressor and no reducers shall be provided for proper oil return.

g. After the refrigerant piping installation has been completed,the refrigerant piping system shall be pressure tested using Freon mixed with nitrogen/ carbondioxide a ta pressure of 20 kgpersq. cm(high side)and 10 kg per sq. cm (low side). Pressure shall be maintained in the system for a minimum of 12 hours.The system shall then be evacuated to a minimum vacuum of 70 cmof mercury and held for 24 hours. Vacuum shall be checked with a vacuum gage.

h. Allrefrigeration piping shall be installed strictly as per the instructions and recommendations of airconditioning equipment manufacturer.

5.4 Piping Installation

a. Design Drawings indicate schematically the size and location of pipes. The Contractor, onaward of the work, shall prepare detailed shop drawings, showing thecross-section,longitudinal sections,details of fittings, locations of isolating and control valves, drain andair valves, and all pipe supports. He must keep in viewthe specificopeningsinthe building through which pipes are designed to pass.

Pipe shall be cut only with hack saw blades and welding rods shall not be used for this purpose. All the pipes shall be cleaned and applied with one coat of Zinc chromate primer.

b. Piping shall be properly supported on, or suspended from, stands, clamps, hangers as specified and as required. The Contractorshalladequately designallthebrackets, saddles,anchors, clamps and hangers and beresponsible for their structural sufficiency.

All pipes in HVAC plant room shall be supported with pipes and channels from floor only with necessary PUF pipe supports and resistoflex sheet.

c. Pipe supports shall be of steel, adjustableforheight andZinc chromate primer coatedandfinish coatedblack.Where pipe and clamps areofdissimilar materials, a gasket shall be provided in between. Spacing of pipe supports shall not exceed the following :

Pipe size	Spacing between supports	Rod Size
Upto12 mm	1.5 Meter	10 mm
15 to25 mm	2.0 meter	10 mm
30 to 150 mm	2.0 meter	10 mm
Over150 mm	2.5 meter	12.5 mm

d. Vertical pipes passing through floors shall be plumb and parallel to wall. Pipes shall be supported on alternate floor. MS cleats shall be welded on pipes and rest on MS channel placed on the floor with 15 mm thick resistoflex pads between the cleat and channel. U clamps with resistoflex sheet shall be provided to keep the pipe in position.

e. Bull heading in water/refrigerant piping shall be avoided.

f. Pipe sleeves atleast 3 mm thick, 50 mm / 100 mm larger in diameter than condenser/chilled water pipes respectively shall be provided where ever pipes pass through **retaining** wall and slab. Annular space shall be filled with fibreglass and finished with retainer rings welded on the ends of the sleeve.

g. Wherever pipes pass through the brick or masonry / slab openings, the gaps shall be sealed with **fire sealant** such as fire barrier caulks.

h. Insulated piping shall be supported in such a manner as not to put undue pressure on the insulation. 20 gauge metal sheet shall be provided between the insulationand the clamp, saddle or roller, extending atleast 15 cm on both sides of the clamp, saddles or roller.

j. Allpiping work shall be carried out in a work men like manner,causing minimumdisturbance to the existing services,buildings and structure.The entire piping work shall be organized,in consultation with other agencies work, so that laying of pipes,supports, and pressure testing for each area shall be carried out in one stretch.

k. Cut-outsin the floor slabs for installing the various pipes are indicated in the Drawings.Contractor shall carefully examine the cut-outs provided and clearly point out where the cut-outs shown in the Drawings do not meet with the requirements.

l. The Contractor shall make sure that the clamps, brackets, clamp saddles and hangers provided for pipe supportsare adequate. Piping layout shall take due care for expansion andcontractionin pipes and include expansion joints where required.

m. All pipes shall be accurately cut to the required size in accordance with relevant BIS Codes, edges bevelled and burrs removed before laying. Open ends of the piping shall be closedasthe pipe isinstalled to avoid entrance of foreign matter. Where reducers are

to be made in horizontal runs, eccentric reducers shall be usedfor the piping to drain freely.In other locations, concentric reducers may be used.

n. Flanged inspection pieces 1.5 meters long, with bolted flanges on both ends, shall be provided no more than 30 meters centres, or where-ever shown in Approved-for-Construction shop drawings, to facilitate future cleaning of all welded pipes.

o. All buried pipes shall be cleaned and coated with zinc chromate primer and bitumen paint,and placed on concrete blocks with PUFsaddles dipped in bitumen at every2 meters and wrapped with three layers of fibre glass tissue, each layer laid in bitumen.

q. Auto purge valves shall be provided at all highest points in thepiping system for venting air. Air valves shall be 15 mm pipe size with screwed joints.

Dischargefrom the air valves shall be piped throughan equalsized mild steel or galvanized steel pipetothe nearest drain or sump. These pipes shall be pitched towards drain points.

r. Whenever services like piping, ducting and cabling are passing through floor slab, shaft or fire zone wall, opening around services shall be closed with fire retardant material. Contractor shall use either fire compound or fire barriers for this purpose. Fire compound shall be in form of powder and shall be mixed with water in proportion suggested by OEM. Mixed compound shall be poured in shuttering and grid of 30 x 30 x 1.2mm angles placed as 150mm center to center. Minimum thickness of pour shall be 100mm and shall be for fire integrity of 120minutes. Angles shall be securely welded to building re-bars (if left during construction) or fastened to concrete floor.

Fire barrier shall be in form of high density rock wool slabs with surface treated for fire retardation. Minimum thickness of the slab shall be 100mm and shall be for fire integrity of 120 minutes. Slabs shall be tightly friction fitted in the shaft to cover all open spaces.

Measurement will be on area basis of applied projected area (in m^2 / ft^2).

5.5 Steel Wire Rope Hangers & Supports:

Wire Hangers shall be used to suspend all static HVAC & Mechanical services.

Wire Hangers should consist of a pre-formed wire rope sling with a range of end fixings to fit various substrates and service fixings, these include a ferruled loop, permanently fixed threaded M6 (or M8, M10) stud, permanently fixed nipple end with toggle, at one end or hook or eyelet, cladding hook, barrel, wedge anchor, eyebolt anchor or any other end fixture type or size as per manufacturers recommendation and design. The end fixings and the wire must be of the same manufacturer with several options available. The system should be secured and tensioned with a Hanger self-locking grip (double channel lock) at the other end. Once the grip is locked for safety purpose unlocking should only be done by using a separate setting key and should not be an integral part of the self-locking grip. Only wire and/or supports supplied and/or approved, shall be used with the system.

a. Wire Hangers should have been independently tested by Lloyds Register. APAVE, TUV, UL NEBS, CSA, Chiltern International fire, ADCAS, Intertek, ECA, and SMACNA, approved by ULC and CSA and comply with the requirements of DW/144 and BSRIA – wire Rope Suspension systems. Wire rope should be manufactured to BSEN 12185: 2002

b. The contractor shall select the correct specification of wire hanger to use for supporting each particular service from Table 1 below. Each size is designated with a maximum safe working load limit (which incorporates a 5:1 safety factor).

The correct specification of wire hanger required is determined using the following formula.

Weight per meter of object suspended (kg) X distance between suspension points (m) = weight loading per Hanger suspension point (kg).

Where the installed wire rope is not vertical then the working load limit shall be reduced in accordance with the recommendations give in the manufacturer's handbook.

The contractor shall select the correct length of wire rope required to support the service. Lengths from 1-10m lengths. Specials can be made, check with manufacturer. No in–line joints should be made in the rope.

Table. 1

Wire (Gripple) Hanger Safe Working Loads		
Hange rsize	**minimum breaking load of Wire Rope (kg/lbs)**	**working load limit (kg/lbs)**
No. 1	80kg/176 lbs	0-10 kg / 0-22 lbs
No. 2	260kg/572 lbs	10-45 kg / 23-100 lbs
No. 3	580kg/1276 lbs	45-90 kg / 101-200 lbs
No. 4	1500kg/3300 lbs	90-225 kg / 210-495 lbs
No. 5	2160kg/4752 lbs	225-325 kg / 496-715 lbs
No. 6	2500kg/5500 lbs	325-500 kg / 715-1100 lbs

The standard range of Hanger Kits should contain galvanized high tensile steel wire rope or stainless steel wire rope as per the application, the minimum specification is as above and should be manufactured to BS 302 (1987), BSEN12185. **Comply with manufacturer's load ratings and recommended installation procedures.**

5.5.1 Mechanical Supports– Gripple Hanger Supports are suitable for: Water Pipes, Drainage Pipes, Gas Pipes, Refrigeration Pipes, Condensation Water Pipes.

5.5.2 Piping Supports: Rigid supports may be used in conjunction with Gripple hangers to assist with alignment of services as per the Schedule. These can be at 30m intervals or so depending on the run of the service. Rigid support must also be used in conjunction with Gripple hangers with pipe work at each change of direction or connection or as per approved drawings. For insulated pipe, provide protective sleeve to protect the entire circumference of the pipe insulation. Stainless Steel Supports should be available for food, chemical and High Corrosion areas near coastlines.

5.5.3 Any other Gripple solution can be used based on manufacturer's recommendation on site conditions after prior approval. Support piping in accordance with Schedule I, II & III specified below:

5.5.4 For further technical information, refer to manufacturers catalogue and installation guide. **Comply with manufacturer's load ratings and recommended installation procedures. All supporting system to be provided by same manufacturer.**

SCHEDULE – I : BARE PIPE / PIPE INSULATED WITH NITRILE RUBBER

Pipe Size (mm dia)	**Wt. of Pipe + Water + insulation (kg / mt)**	**Spacing between pipe supports (mt)**	**Total Wt of Pipe between two supports (kg)**	**Gripple Hanger size**
12-40	7	2	14	No. 2
50-65	15.22	2	30	No. 2

80	14.73	2	69	No. 3
100-200	73	2	146	No. 4
250 & above	Rigid supports to be used as per pipe hanger Schedule – III			

SCHEDULE – II : PIPE INSULATED WITH EXPANDED POLYSTERENE & COVERED WITH SAND CEMENT PLASTER

Pipe Size (mm dia)	Wt. of Pipe + Water + insulation (kg / mt)	Spacing between pipe supports (mt)	Total Wt of Pipe between two supports (kg)	Gripple Hanger size
12-40	14	2	10	No. 2
50-65	20	2	40	No. 3
80	44.67	2	89.14	No. 4
100-200	83	2	166	No. 4
250 & above	Rigid supports to be used as per pipe hanger Schedule – III			

Pipe Hanger Schedule III:

Rigid Supports for pipes to be used in conjunction with wire supports:

Rigid supports if required in conjunction with wire hangers shall be of steel, adjustable for height and Zinc chromate primer coated and finish coated black. Where supports and clamps are of dissimilar materials, a gasket shall be provided in between.

PIPE SIZE (mm)	PIPE SUPPORT	
UP TO 50 Ø	40×40×6 M.S ANGLE	
80Ø TO 100Ø	50×50×6 M.S ANGLE	
PIPE SIZE (mm)	**HORIZONTAL SUPPORT**	**VERTICAL SUPPORT**
125Ø TO 200Ø	75×40 M.S CHANNEL	50×50×6 M.S ANGLE
250Ø TO 300Ø	100×50 M.S CHANNEL	75×40 M.S CHANNEL
300Ø TO 400Ø	150×75 M.S CHANNEL	100×50 M.S CHANNEL
450Ø TO 600Ø	200×75 M.S CHANNEL	200×75 M.S CHANNEL

5.6 Testing

a. During construction , the contractor shall properly cap all lines, so as to prevent the entrance of sand, dirt, etc. Each system of piping shall be flushed thoroughly after completion (for the purpose of removing dirt, grit, sand etc. from the piping and fittings) for as long a time as is required to thoroughly clean the system.

b. Allpiping shall be tested to hydrostatic testpressure ofat leasttwotimesthemaximumoperating pressure,but not less than 10 kg per sq. cm gagefora periodof not less than 24 hours. All leaks anddefects in joints revealed during the testing shall berectified, retestedand gotten approved

c. Pipingrepairedsubsequent to the abovepressuretest shall be re-tested in the same manner.

d. Piping may be tested in sections and such sectionsshall be securely capped, then re-tested for the entire system.

e. The Contractor shall give sufficient notice to allother agenciesat site, of his intention to test asectionor sections of piping and all testing shall be witnessed and recorded by Owner's site representative.

f. The contractors shall provide temporary pipe connections to initially by-pass condenser/chiller and circulate water through condenser/chilled water pipe lines for

minimum 8 hours. Water should be drained out from the lowest point. The temporary lines shall be removed and blanked with dead flanges. Pot strainers and Y strainers shall be cleaned and fresh water filled in the circuits.

g. After regular flushing, as per 'f' above, all systems shall be chemically cleaned. Chemical cleaning shall be carried out in 3 stages. In first stage biological cleaning shall be done to remove algae, bacteria, SRB etc which produces slimes. Second stage is pre-cleaning in which loose rust, oil, and debris are removed. Chemical addition and hold up time shall be as per chemical supply agencies recommendations. Third stage is passivation, in which chemicals will be added and passivation film will be formed over inside surfaces of piping system. Type of chemical used and quantity of the same along with detailed method statement shall be submitted by contractor for consultants' approval before starting this activity.

Before handover Owner's site representative shall be provided with certificate of cleaning of pipe systems, signed by thecontractor.

h. Afterthe piping has been installed, tested and runfor atleastthreedaysof eight hourseach,allinsulated exposed pipinginplantroomshallbegiventwo finish coats, 3 mils each of approved colour,conforming to relevant BIS Codes.
The direction of flow of fluidin the pipes shall be visibly marked with identifying arrows. For painting of insulated and clad pipes refer to Insulation section.

j. TheContractorshall make surethatpropernoiseless circulationof fluid is achieved through allcoilsand other heat exchange equipment in the system concerned. If propercirculationisnot achieved duetoairbound connection,the Contractor shall rectifythedefective connections. He shall bear all expenses for carryingout the above rectifications including the tearing up and re-finishing of floors and walls if required.

k. TheContractorshallprovideallmaterials,tools, equipment,instruments, services and labour requiredto performthetestand to removewaterresultingfrom cleaning and after testing.

5.7 Balancing

a. Aftercompletion of the installation, allwatersystem shallbeadjustedand balanced todeliverthewater quantities as specified, quoted, or as directed.

b. All balancing valves, Automaticcontrol valves and two-way divertingvalves shallbesetforfull flowconditionduringbalancingprocedure.Each water circuit shall be adjusted thru balancing valves provided for this purpose; these shall bepermanently markedafter balancing is completed, so that they canbe restored to their correct positions, if disturbed.

c. Completecertified balancing report shallbesubmitted forevaluation and approval by Owner's site representative. Upon approval, fourcopies ofthe balancing report shall be submitted withtheas-installed drawings and completion documents.

5.8 Valve Identification

Provide 30 mm dia brass valve tag, with embossed letters and number for each valve and attach the tag to valve handle by "S" hook or by suitable means. Contractor shall provide valve tag schedule and valve chart for each piping system, consisting of schematic drawing of piping layout, along with a valve list, showing and identifying each valve by number, service and location and describing its function.

The contractor shall frame under glass in the airconditioning plant room or as directed by Owner's site representative two copies of valve chart. Two additional unmounted copies shall be supplied to the Owner's site representative.

Tags shall correspond with the valve schedule and record drawings. In back of house areas, where ceilings are installed and the valve or valve tag is not visible, a self adhering tag with the valve number shall be installed on the wall or directly under the ceiling.For public area ceiling valves, these tags are to be installed in the service corridor, leading to the public areas.

5.9 Measurement For Piping

Unlessspecified otherwise, measurement for pipingforthe projectshallbe on the basis of centrelinemeasurements described herewith.

Pipingshall be measured in units of length along the centre line of installed pipes including all pipe fittings,flanges (with gaskets, nuts, and bolts for jointing), unions,bends, elbows,tees,concentricand/oreccentricreducers,inspection pieces, expansion loops etc. The above accessories shall be measured as part of piping lengthalong thecentre lineofinstalled pipes, and no special multiplesofpipe lengths for accessories shall be permitted.

Thequotedratesfor centre linelinearmeasurementsof pipingshall include all wastage allowances,pipesupports includinghangers, MS channel, PUF supports, nuts,check nuts,vibrationisolatorsuspensionwherespecifiedor required, and any other item required to complete thepiping installationas per the Specifications. None of theseitems will be separately measured nor paid for.

However, all valves (gate / globe / check / balancing / purge /butterfly / drain etc), strainers,thermometers,pressure gagesshallbeseparately counted and paidaspertheir individualunitrates,whichshallalsoincludetheir insulationas per Specifications. Piping measurementsshall be taken before application of the insulation.

Contractor shall get pressure testing of pipes/measurements etc verified by the Owners representative at site.

6. AIR DISTRIBUTION

(FOR DUCTS FABRICATED IN FACTORYAS PER "SMACNA" STANDARDS)

6.1 Scope

The scope of this section comprises supply fabrication, installation and testing of all sheet metal / aluminum ducts, supply, installation, testing and balancing of all grilles, registers and diffusers. All to be in accordance with these specifications and the general arrangement shown on the Drawings.

6.2 Duct Materials

6.2.1 Raw Materials

Galvanized steel sheets with Class - VII Galvanizing – light coating of zinc (Zinc coating shall be Lead free), nominal 120 gm/sq.m surface area and Lock Forming Quality prime material along with mill test certificates. In addition, if deemed necessary, samples of raw material, selected at random by owner's site representative shall be subject to approval and tested for thickness and zinc coating at contractor's expense.

6.2.2 Gauges, Bracing By Size Of Ducts

All ducts shall be factory fabricated from galvanized steel / aluminum of the following thickness, as indicated below :

6.2.2.1 For Ducts with External SP upto 500 Pa

Rectangular Ducts G. S.	**External Pressure 500 Pa**		
	Duct Section Length1.2 m (4 ft)		
Maximum Duct Size	**Gauge**	**Joint Type**	**Bracing Spacing**
1-600 mm	24	C&S Connector	Nil
601-1000 mm	22	TDF Flange	Nil
1001-1200 mm	20	TDF Flange	JTR or ZEE BAR
1201-2100 mm	20	TDF Flange	JTR or ZEE BAR
2101-above	18	TDF Flange	JTR or ZEE BAR

6.3 Fabrication Standards & Equipment

All duct construction and installation shall be in accordance with SMACNA standards. In addition ducts shall be factory fabricated utilizing the following machines to provide the requisite quality of ducts

1. Coil (Sheet metal in Roll Form) lines to facilitate location of longitudinal seams at corners/folded edges only, for required duct rigidity and leakage free characteristics. No longitudinal seams permitted along any face side of the duct.
2. Factory fabricated and factory boxed ducts shall be used upto 1 M side. Ducts above 1M side may be supplied to site in L profiles.
3. All ducts, transformation pieces and fittings to be made on CNC profile cutter for requisite accuracy of dimensions, location and dimensions of notches at the folding lines
4. All edges to be machine treated using lock formers, flangers and rollers for turning up edges
5. In the case of ambiguity, SMACNA codes to be followed for duct fabrication and installation
6. Kitchen exhaust ducting shall be with 16 G MS / **18G SS** welded construction. Suitable access doors shall be provided at every 3m. Provision shall be made for firefighting agency to install duct mounted sprinklers at every 3m. Generally exhaust ducts shall have slope

towards kitchen hood. Spot Welded M.S Stuck-up pins shall be provided facilitating insulation of the Duct

7. Laundry and dish washer extract duct shall be air and water tight construction manufactured from Aluminium sheets in accordance to BS 1470

6.4 Duct Construction

6.4.1 All ducts shall be fabricated and installed in workmanlike manner, conforming to relevant SMACNA codes.

a) Ducts so identified on the Drawings shall be acoustically lined and insulated ~~from outside~~ as described in the section "Insulation" and as indicated in schedule of Quantities. Duct dimensions shown on drawings, are overall sheet metal dimensions inclusive of the acoustic lining where required and indicated in Schedule of quantities. The fabricated duct dimensions should be as per approved drawings and care should be taken to ensure that all connecting sections are dimensionally matched to avoid any gaps.

b) Ducts shall be straight and smooth on the inside with longitudinal seams shall be airtight and at corners only which shall be either Pittsburgh or snap button as per SMACNA practice, to ensure air tightness.

c) Changes in dimensions and shape of ducts shall be gradual (between 1:4 and 1:7). Air-turns (vanes) shall be installed in all bends and duct collars designed to permit the air to make the turn without appreciable turbulence.

d) Ducts shall be fabricated as per details shown on Drawings. All ducts shall be rigid and shall be adequately supported and braced where required with standing seams, tees, or angles, of ample size to keep the ducts true to shape and to prevent buckling, vibration or breathing.

e) All sheet metal connection, partitions and plenums, required to confine the flow of air to and through the filters and fans, shall be constructed of 18 gauge GSS / 16gauge aluminum, thoroughly stiffened with 25mm x 25mm x 3mm galvanized steel angle braces or equivalent stiffening as per SMACNA and fitted with all necessary inspection doors as required, to give access to all parts of the apparatus. Alternatively, plenums can be made in multiple parts and joined with 4 Bolt slip-on flange system with suitable reinforcement as per SMACNA. Access doors shall be not less than 45cm x 45cm in size.

f) Plenums shall be shop/factory fabricated panel type and assembled at site. Fixing of galvanized angle flanges on duct pieces shall be with rivets heads inside i.e. towards GS sheet and riveting shall be done from outside.

g) Self-adhesive Neoprene rubber / UV resistant PVC foam lining 5mm nominal thickness instead of felt, shall be used between duct flanges and between duct supports in all ducting installation.

h) All fire rated duct, smoke exhaust ducts shall be quoted with flamebar BWII or equivalent to achieve the required fire rating also all the related accessories gaskets shall be suitable for the required fire rating.

6.5 (Common Specifications for Alternate – I & Alternate – II)

Pre-insulated ducts (if indicated in Schedule of Quantities)

Pre-Insulated Ducting shall be fabricated from 20 mm thickness air duct panel sheet having dimensions of 3000 (Length) mm by 1200 (Width) mm and produced and Sandwiched with

Polyisocyanurate (PIR) first quality insulating Foam having 15 Kg / m^3 density. The Ducting Sheet shall have Lacquered & Embossed Aluminium facing on both sides.

Insulating foam material shall be Expanded Rigid Polyisocyanurate foam having Closed cell content not less than 95%, CFC/ HCFC free, Non Toxic, Noncombustible, zero ozone depletion, Zero Global Warming Potential and Non ignitable.

Ducting panels shall comply with following or equivalent standards and manufacturer should produce M1 & F1 certification for Fire & Toxicity test results.

- BS 476: PART 6--Fire Propagation for Products
- BS 476: PART 7--- Surface Flame Spread (Class 1)
- Class O Fire Rating as per Building Regulation requirements.
- Thermal Conductivity Coefficient at 10^0C--0.022 W/m. K
- Smoke Opacity Index—less than 10
- Rigidity class: 200000 Nm m^2/mm
- Water vapor permeability of laminations = 0

All required accessories; Connecting Flanges, Invisible Bayonet, Adhesive, Sealant, Duct Supports shall be part of ducting work for fabrication of the HVAC ducting in Square, rectangle, radius, offset construction etc., appropriate sizes of Aluminium flanges with self-adhesive good quality gasket shall be provided as a joinery or connection of duct pieces.

Excellent quality Silicon Neutral Sealant of Approved make along with fire rated PVC corners shall be used for sealing of all joints & corners.

Complete ducting shall be installed incorporating duct supports such as galvanized angles, threaded rods, self adhesive brackets, etc.

Panel Specifications: --

Description	**Internal Areas of Building**	**External Areas of Building**
Dimensions of panel	3000 x 1200 mm	3000 x 1200 mm
Thickness of panel	20 mm	20/30 mm
Thickness of aluminium laminations	60/60 microns	60/200 microns
Density of the foam	15 kg/m^3	15 kg/m^3
Surface finish	Embossed both sides	Embossed both sides
Anti-rust lacquer	2 gm/m^2 both sides	2 gm/m^2 both sides

6.6 Installation Practice

All ducts shall be installed generally as per tender drawings, and in strict accordance with approved shop drawings to be prepared by the Contractor:

a) The Contractor shall provide and neatly erect all sheet metal work as may be required to carry out the intent of these Specifications and Drawings. The work shall meet with the approval of Owner's site representative in all its parts and details

b) All necessary allowances and provisions shall be made by the Contractor for beams, pipes, or other obstructions in the building, whether or not the same are shown on the drawings. Where necessary to avoid beams or other structural work, plumbing or other pipes, and conduits, the ducts shall be transformed, divided or curved to one side (the required area being maintained) all as per the site requirements.

c) If a duct cannot be run as shown on the drawings, the contractor shall install the duct between the required points by any path available in accordance with other services and as per approval of owner's site representative.

d) All ductwork shall be independently supported from building construction. All horizontal ducts shall be rigidly and securely supported, in an approved manner, with hangers formed of galvanized steel wire ropes (as per clause 27.13) or threaded rods and galvanized steel angle/channel or a pair of brackets, connected by galvanized steel wire hangers under ducts, rigid supports may be provided at certain interval if need be. The spacing between supports should be not greater than 2.4 meter. All vertical ductwork shall be supported by structural members on each floor slab or wall as per approved general installation drawings / approved shop drawings. Duct supports may be through galvanized steel insert plates or Toggle end wire fixing left in slab at the time of slab casting.

Galvanized steel cleat with a hole for passing the wire rope hanger shall be welded to the plates. Trapeze hanger formed of galvanized steel wire rope using using braided wire rope shall be hung through these cleats. Wherever use of metal insert plates is not feasible, duct support shall be through dash/anchor fastener driven into the concrete slab by electrically operated gun. Wire rope supports shall hang through the cleats or wire rope threaded studs can be screwed into the anchor fasteners. In case of threaded rods, the rod diameters shall be as per table provided in standard installation sketches.

e) Alternatively, if mentioned in the SOQ, all ductwork shall be independently supported from building construction. All horizontal ducts shall be rigidly and securely supported, in an approved manner, with trapeze hangers formed of galvanized steel rods and galvanized steel angle/channel or a pair of brackets, connected by galvanized steel rod under ducts**.** The spacing between supports should be not greater than ~~2.0~~ 2.4 meter. All vertical ductwork shall be supported by structural members on each floor slab. Duct supports may be through galvanized steel insert plates left in slab at the time of slab casting. Galvanized steel cleat with a hole for passing the hanger rods shall be welded to the plates. Trapeze hanger formed of galvanized steel rods shall be hung through these cleats. Wherever use of metal insert plates is not feasible, duct support shall be through dash/anchor fastener driven into the concrete slab by electrically operated gun. Hanger rods shall then hang through the cleats or fully threaded galvanized rods can be screwed into the anchor fasteners.

f) Ducting over furred ceiling shall be supported from the slab above, or from beams after obtaining approval of Owner's site representative. In no case shall any duct be supported from false ceiling hangers or be permitted to rest on false ceiling. All metal work in dead or furred down spaces shall be erected in time to occasion no delay to other contractor's work in the building.

g) Where ducts pass through brick or masonry openings, it shall be provided with 25mm thick **TF quality expanded polystyrene around the duct and totally covered with fire barrier mortar for complete sealing.**

h) All ducts shall be totally free from vibration under all conditions of operation. Whenever ductwork is connected to fans, air handling units or blower coil units that may cause vibration in the ducts, ducts shall be provided with a flexible connection, located at the unit discharge. Flexible connections shall be constructed of fire retarding flexible heavy canvas sleeve at least 10cm long securely bonded and bolted on both sides. Sleeve shall be made smooth and the connecting ductwork rigidly held by independent supports on both sides of the flexible connection. The flexible connection shall be suitable for pressure at the point of installation.

i) Duct shall not rest on false ceiling and shall be flat bottom type. Taper pieces shall taper from top.

6.7 Dampers

a. Dampers: All duct dampers shall be opposed blade louver dampers of robust ~~16 G~~ 18 GSS construction and tight fitting. The design, method of handling and control shall be suitable for the location and service required.

b. Dampers shall be provided with suitable links levers and quadrants as required for their proper operation. Control or setting device shall be made robust, easily operable and accessible through suitable access door in the duct. Every damper shall have an indicating device clearly showing the damper position at all times.

c. Dampers shall be placed in ducts at every branch supply or return air duct connection, whether or not indicated on the Drawings, for the proper volume control and balancing of the air distribution system.

d. Pressure relief dampers: Pressure relief dampers shall be constructed with 18G Aluminum construction with parallel blade construction. Leafs shall be 100% air tight upon closure. Leafs shall be loaded with spring pressure of stiffness (k value) or counter weight corresponding to set point pressure.

e. Non return damper (Back draft damper) : Non return damper shall be constructed out of ~~16G~~ 18G GSS. Blades shall ensure 100% air leak proof performance on closure. Design shall ensure that no rattling noise is produced at design duty.

f. Constant Volume Regulator (For Hotel/ Hospital TFA / Exhaust ducts)

Constant volume regulators (KVR) shall be used to obtain constant air volume at a given pressure range.

The constant volume regulators (KVR) shall be of the circular type for high pressures and to be inserted into ductwork and suitable for vertical as well as horizontal mounting and it should be placed at a minimum distance of 3x the duct diameter from air supply grilles and minimum distance of 1x the duct diameter from air exhaust grilles

Constant volume regulator body, valve and piston shall be made out of flame retardant PVC, fire classification M1. They shall contain a self regulating PVC valve, piston, rubber strip for air tightness inside the duct and stainless steel calibrated spring and shall have preset air volume.

Constant volume regulator shall be made of PVC. The range covers an air flow range from 15 up to 1200 m^3/h within a pressure range from 50 up to 600 Pa.

6.8 Fire & Smoke Dampers

a. All supply and return air ducts at AHU room crossings and at all floor crossings or as indicated in the drawings shall be provided with Motor operated Fire & smoke damper of at least 90 minutes rating. These shall be of multi-leaf type and provided with Spring Return electrical actuator having its own thermal trip for ambient air temperature outside the duct and air temperature inside the duct. Actuator shall have Form fit type of

mounting, metal enclosure and guaranteed long life span. The dampers shall meet the requirements of NFPA90A, 92A and 92B. Dampers shall have a fire rating of 1.5 Hrs. in accordance with latest edition of UL555 and shall be classified as Leakage Class ~~2~~ 1 smoke damper in accordance with latest version of UL555S. Each fire/smoke damper shall be AMCA licensed and bear the AMCA seal for air Performance. Pressure drop shall not exceed 7.5Pa when tested at 300m/min face velocity on 600x600mm size damper. Actuator shall be UL listed.

b. Each damper shall be supplied with factory mounted sleeve of galvanized steel of thickness as per SMACNA and of minimum 500mm long or as specified in schedule of quantities depending up on the wall thickness. The damper shall be fitted in to sleeve either using spot welding, crimping or self-tapping screws. All welded joints shall be finished using heat resistance steel paint . UL listed and approved Silicon sealant shall be applied at all corners as well as at joints between damper frame and sleeve. Damper Frame shall be a roll formed structural hat channel , reinforced at corners, formed from a single piece of 1.6mm galvanized steel . Damper blades shall be airfoil shaped (equivalent to 2mm thickness strength) roll formed using 0.7mm thick single piece of galvanized sheet. Bearings shall be of stainless steel fitted in an extruded hole in the damper frame. Blade edge seals shall be silicone rubber and galvanized steel mechanically locked in to the blade edge (adhesive type seals are not acceptable). Side Jam seals of stainless steel and Top and bottom seals of galvanized steel shall be provided. All galvanized steel used shall be with minimum 180 gm / sqm Zinc coating. Bigger size Dampers shall be supplied in Multiple modules of sizes not exceeding in dimensions of certified module, jack shafted together. Multiple actuators shall be provided for large dampers with higher torque requirements as prescribed in UL.

c. The electric actuator shall be energized either upon receiving a signal from smoke detector installed in AHU room supply air duct / return air duct. Electric Actuator of suitable Torque and as approved by UL shall be factory mounted and tested. The actuator shall be provided with 230V 1 Phase power supply from AHU panel / emergency panel and shall include necessary transformer for its operation. In addition actuator shall have elevated temperature rating of 250 deg.F. Electric Actuator shall have been energized hold open tested for a period of at least one year with no spring return failure. Each fire/smoke damper shall be equipped with a heat actuated release device which shall allow controlled closure of damper rather than instantaneous to prevent accident.(Electrical fusible link).The EFL shall allow the damper to reopen automatically after a test, smoke detection or power failure condition. The damper shall be equipped with a device to indicate OPEN and CLOSE position of Damper blades through a link mounted on the damper blade.

d. Each damper shall be provided with its own control panel, mounted on the wall and suitable for 240 VAC supply. This control panel shall be suitable for spring return actuator and shall have atleast the following features:

- Potential free contacts for AHU fan ON/ Off and remote alarm indication.
- Accept signal from external smoke / fire detection system for tripping the electrical actuator.
- Test and reset facility.
- Indicating lights / contacts to indicate the following status:
- Power Supply On
- Alarm
- Damper open and close position.

e. Actuators shall be mounted on the sleeve by the damper supplier in his shop and shall furnish test certificate for satisfactory operation of each Motor Operated Damper in conjunction with it's control panel. Control panel shall be wall mounted type.

f. It shall be HVAC Contractor's responsibility to co-ordinate with the Fire Alarm System Contractor for correctly hooking up the Motor Operated Damper to Fire Detection / Fire Management System. All necessary materials including power cabling between control panels to fire dampers actuator for hooking up shall be supplied and installed by HVAC Contractor under close co-ordination with the fire protection system contractor.

g. HVAC Contractor shall demonstrate the testing of all Dampers and its control panel after necessary hook up with the fire protection / fire management system is carried out by energizing all the smoke detectors with the help of smoke.

h. HVAC Contractor shall provide Fire retardant cables wherever required for satisfactory operation and control of the Damper.

j. HVAC Contractor shall strictly follow the instructions of the Damper Supplier or avail his services at site before carrying out testing and installation at site.

k. Fire/smoke damper shall be provided with factory fitted sleeves and connecting flange and mounting angles for installation; however, access doors shall be provided in the ducts within AHU room in accordance with the manufacturer's recommendations.

l. The Contractor shall also furnish to the Owner, the necessary additional spare actuators and temperature sensor (a minimum of 5% of the total number installed) at the time of commissioning of the installation.

6.9 Fire Dampers

a. Whenever a supply/return duct crosses from one fire zone to another, it shall be provided with approved fire damper of at least 1½ hour fire rating as per UL555/1995 tested by CBRI. This shall be curtain type or multileaf type fire damper.

b. Curtain type fire damper blades shall be one piece folded high strength ~~16G~~ minimum 24G galvanized steel construction. In normal position, these blades shall be gathered and stacked at the frame head providing maximum air passage and preventing passing air currents from creating noise or chatter. The blades shall be held in position through fusible link of temp 74ºC (165°F).

The HVAC contractor shall supply UL classified Fire Dampers meeting or exceeding the specifications. Fire Dampers shall be furnished and installed at locations shown in Drawings and as described in Schedule of quantities. Fire Dampers shall have a fire rating of 1.5/3 Hrs.as specified in BOQ, in accordance with latest edition of UL555.

Multileaf type fire damper shall be equipped with UL labelled Fusible Link with Temperature setting 74ºC (165°F) or as specified in Schedule of quantities. Fire dampers shall have been tested to close under dynamic air flow conditions with pressure up to 1000 pa and velocities up to 10.2 m /sec. Fire damper shall be approved for Horizontal or vertical installation as may be required by the location shown in the drawings. Each Fire damper shall be AMCA licenced and shall bear the AMCA seal for air performance.

Damper Frame shall be a roll formed structural hat channel, reinforced at corners, formed from a single piece of 1.0mm galvanized steel. Damper blades shall be roll formed 3-v groove (1.6mm thick) or airfoil shaped in case of 3 Hrs. fire rating (equivalent to 2.0mm thickness strength) roll formed using 0.7mm thick single piece of galvanized sheet. Bearings shall be of stainless steel fitted in an extruded hole in the damper frame. All galvanized steel used shall be with minimum 180 gm / sqm Zinc coating Bigger size Dampers shall be supplied in Multiple modules of sizes not exceeding in dimensions of certified module jack shafted together.

Fire damper shall be equipped with a electric limit switch to indicate open and close position of the damper blades.

Fire Damper shall be installed in wall or floor opening using galvanized steel sleeve of minimum 500mm length of sheet thickness for fire & smoke damper as per SMACNA and as per Installation instruction of Manufacturer.

c. In case of fire, the intrinsic energy of the folded blades shall be utilized to close the opening. The thrust of the suddenly released tension shall instantly drive the blades down and keep it down without the use of springs, weights or other devices subject to failure.

d. Fire damper sleeves and access doors shall be provided within the duct in accordance with the manufacturer's recommendation.

e. The contractor shall also furnish to the Owner, the necessary additional fusible links (spares), minimum of 5% of the total number installed, at the time of commissioning of the installation.

6.10 Supply And Return Air Registers

Supply & return air registers shall be of either steel or aluminium sections as specified in schedule of quantities. Steel construction registers shall have primer Coat finish whereas extruded aluminium registers shall be either Anodised or Powder Coated as specified in Schedule of Quantities. These registers shall have individually adjustable louvers both horizontal and vertical. Supply air registers shall be provided with key operated opposed blade extruded aluminium volume control damper anodised in matt black shade. The register should be constructed with 1 mm thick frame, blade of 0.8 mm thick and opposed blade dampers of 1 mm thick.

The registers shall be suitable for fixing arrangement having concealed screws as approved by Architect. Linear continuous supply cum return air register shall be extruded aluminium construction with fixed horizontal bars at 15 Deg. inclination & flange on two sides only. The thickness of the fixed bar louvers shall be minimum ~~5.5 mm~~ 5mm in front and 3.8 mm in rear with rounded edges. Flanges on the two sides shall be 20 mm/30 mm wide as approved by Architect.

The grilles shall be suitable for concealed fixing. Volume control dampers of extruded aluminium anodised in black color shall be provided in supply air duct collars. For fan coil units horizontal fixed bar grilles as described above shall be provided with flanges on four sides, and the core shall be & suitable for clip fixing, permitting its removal without disturbing the flanges.

a. All registers shall be selected in consultation with the Architect. Different spaces shall require horizontal or vertical face bars, and different width of margin frames. These shall be procured only after obtaining written approval from Architect for each type of register.

b. All registers shall have a soft continuous rubber/foam gasket between the periphery of the register and the surface on which it has to be mounted. The effective area of the registers for air flow shall not be less than 66 percent of gross face area.

c. Registers specified with individually adjustable bars shall have adjustable pattern as each grille bar shall be pivotable to provide pattern with 0 to +45 degree horizontal arc and upto 30 degree deflection downwards. Bars shall hold deflection settings under all conditions of velocity and pressure.

d. Bar longer than 45 cm shall be reinforced by set-back vertical members of approved thickness.

e. All volume control dampers shall be anodised aluminium in mat black shade having 1 mm minimum thickness.

6.11 Supply And Return Air Diffusers

Supply and return air diffusers shall be as shown on the Drawings and indicated in Schedule of Quantities. Mild steel diffusers/dampers shall be factory coated with rust-resistant primer. Aluminium diffusers shall be powder coated & made from extruded aluminium section as specified in schedule of quantities. The diffuser should be constructed with 1 mm thick frame, blade of 0.8 mm thick and opposed blade dampers of 1 mm thick.

a. Rectangular Diffusers shall be steel / extruded aluminium construction, square & rectangular diffusers with flush fixed pattern for different spaces as per schedule of quantities These shall be selected in consultation with the Architect. These shall be procured only after obtaining written approval from Architect for each type of diffuser.

b. Supply air diffusers shall be equipped with fixed air distribution grids, removable key-operated volume control dampers, and anti-smudge rings as re-required in specific applications and as per requirements of schedule of quantities. All extruded aluminium diffusers shall be provided with removable central core and concealed key operation for volume control damper.

c. Linear Diffuser shall be extruded aluminium construction with removable core, one or two way blow type. Supply air diffusers shall be provided with volume control/ balancing dampers within the supply air collar. Diffusers for different spaces shall be selected in consultation with the Architect, and provided as per requirements of schedule of quantities. All diffusers shall have volume control dampers of extruded aluminium construction anodised in mat black shade.

d. Slot Diffuser shall be extruded aluminium construction multislot type with air pattern controller provided in each slot. Supply air diffusers shall be provided with Hit & Miss volume control dampers in each slot of the supply air diffusers. Diffusers for different spaces shall be selected in consultation with the Architect and provided as per requirement of Schedule of Quantities.

e. Data centers shall be provided with floor grilles. Grilles shall be of nominal size of 600mm x 600mm and shall be fitted in floor tile of false floor. Grille shall be with dampers for flow control. Grill shall be heavy duty 16G Aluminium and shall take care

of human traffic load. Damper shall be operable in situ without requirement of removal of grille.

6.12 Fire Rated Ductwork

Ducting for kitchen exhaust & fire evacuation, staircase pressurization if not in a separate shaft shall be fire rated as per following specifications.

a. All fire rated ductwork constructed for mechanical or dual ventilation / pressurization/ basement car park/smoke extract systems and shall be fabricated from Lock Forming Quality grade prime galvanized steel sheet, constructed to enhanced SMACNA American / DW144 European standard to either low, medium or high velocity/ pressure.

b. Test requirement of fire rated ductwork should be tested to BS476: Part 24 [1987] and ISO 6944 providing required fire rating for Stability and Integrity.

c. Stability: the ability of a duct, ductwork & the support system to remain intact & fulfill their intended function for a specified period of time, when tested to the requirements of BS476: Part 24 and ISO 6944.

d. Integrity: the ability of a duct or ductwork to remain free of cracks, holes or openings outside the compartment in which the fire is present for a specified period of time, when tested to the requirements of BS476 Part 24 ISO 6944.

e. Insulation: the ability of a duct or ductwork to maintain its separating function without developing temperatures on its external surface outside the compartment in which the fire is present, which exceeds, (i) 140^{O}C as an average value above ambient & or, (ii) 180^{O}C as maximum value above ambient at any point, when tested for a specified period of time to the requirements of BS476: Part 24 ISO 6944.

f. Its important that the fire rated ductwork has a smooth internal surface in order to minimize the pressure loss within the fire rated ductwork system thereby reduce the power requirements.

g. All fire rated ducts for Smoke Extract shall have Stability / Integrity and Insulation for smoke temperatures up to 300^{O}C upto 1.5 hrs, restriction of the duct due to twisting or buckling after the fire test shall not cause 25% or more reduction in cross sectional area proven by certification from an independent test house.

h. Each duct shall have fire rated coating. Fire rated coating compound used for construction of fire rated ductwork shall be protected with minimum 0.7mm to 1mm nominal thickness tested to properties as per the requirements of BS 476: 6 & 7, including non-combustibility Class O and fire propagation - Class 1 surface spread of flame & materials in accordance with Building Regulations.

i. Fire duct to be tested / assessed to BS476: Part 24 for all sizes up to 25 meters x 3 meters cross-sectional area and fully certified to vertical and horizontal plane.

j. Fire rated duct fabricated to Method 3 of BS 5588: Part 9, factory produced. The coating compound shall be applied either offsite or onsite on the ground, dried and cured.

k. Fire duct expansion under fire conditions shall not exceed following:

- at 430^{O}C an expansion of 0.006106mm per mm
- at 600^{O}C an expansion of 0.00852mm per mm
- at 1100^{O}C an expansion of 0.01562mm per mm.

6.13.1 HVAC Supports

Braided wire Hanger Supports are suitable for: Rectangular duct, Spiral Duct, Oval Duct, Fabric Duct, Diffusers, plenum boxes

6.13.2 Ducting Supports:

a. All ductwork shall be independently supported from building construction. All horizontal ducts shall be rigidly and securely supported, in an approved manner, with hangers formed of galvanized steel wire ropes and galvanized steel angle/channel or a pair of brackets, connected by galvanized steel wire hangers under ducts, rigid supports may be provided at certain interval if need be. The spacing between supports should be not greater than 2.4 meter or 2 meter, whichever smaller. All vertical ductwork shall be supported by structural members on each floor slab. Duct supports may be through galvanized steel insert plates or Toggle end wire fixing left in slab at the time of slab casting. Galvanized steel cleat with a hole for passing the wire rope hanger shall be welded to the plates. Trapeze hanger formed of galvanized steel wire rope using braided wire supports shall be hung through these cleats. Wherever use of metal insert plates is not feasible, duct support shall be through dash/anchor fastener driven into the concrete slab by electrically operated gun. Wire rope supports shall hang through the cleats or wire rope threaded studs can be screwed into the anchor fasteners. In case of PEB structure Loop and Catenary system can be used based on the site conditions as per approved suspension system drawings.

b. All horizontal ducts shall be adequately secured and supported. In an approved manner, with trapeze Hangers formed of galvanized steel wire rope in a cradle support method (refer to typical drawings) under ducts at no greater than 3000mm centre, for 3001mm-above appropriate size angle along with neoprene pad in between the duct & MS angle should be used with prior approval. All vertical duct work shall be supported by structural members on each floor slab. Duct support shall be through dash / anchor fastener driven into the concrete slab by electrically operated gun. Hanger wires shall then hang around the ducting. Rigid supports shall be used in conjunction with wire rope hangers to assist with alignment of services where recommended for by the manufacturer. Rigid support must also be used in conjunction with wire rope hangers with duct work at each change of direction or connection or as per approved drawings. Support ducting in accordance with Schedule I specified below. Any other braided wire supports solution can be used based on manufacturer’s recommendation on site conditions after prior approval. In cases of Spiral ducting the wire can be wrapped directly around the ducting without the need for a spiral ducting clamp for sizes above 1100 a cradle support should be provided, refer to manufacturer’s recommendations.

c. Ducting over furred ceiling shall be supported from the slab above or from beams after obtaining approval of Construction manager/consultant. In no case shall any duct be supported from false ceiling Hangers or be permitted to rest on false ceiling. All metal work in dead or furred down spaces shall be erected in time to occasion no delay to other Contractor’s work in the building. All supports of pipe shall be taken from structural slab/wall by means of fastener.

Catenary Supports: Refer to manufacturer’s recommendations on Catenary supports with C-clip, special care should be taken with tensioning of the wire and angles at which the installation of services are made**.**

d. Stainless Steel Supports should be provided for food, chemical and High Corrosion areas near coastlines.

For further technical information refer to manufacturers catalogue and installation guide. **Comply with manufacturer's load ratings and recommended installation procedures.**

Schedule I: Duct Hanger Schedule

For ducts with external SP upto 250 Pa	**For ducts with external SP upto 500 Pa**

Maximum Duct Size (mm)	Gauge	Hanger size
1 - 500	26	No. 1 or 2
501 - 750	26	No. 1 or 2
751 - 900	26	No. 2
901 - 1200	24	No. 2 or 3
1201 - 1500	22	No. 3
1501 - 1800	22	No. 3 or 4
1801-2100	20	No. 3 or 4
2101-3000	18	No. 4
3001 - above(Trapeze type support Arrangement)	18	No. 3 or 4

Maximum Duct Size (mm)	Gauge	Hanger size
1–400 mm	26	No. 2
401-700 mm	24	No. 2 or 3
701-900 mm	24	No. 2 or 3
901-1000 mm	22	No. 3 or 4
1001-1200 mm	22	No. 3 or 4
1201-2100 mm	22	No. 3 or 4
2101 - 3000mm	18	No. 4
3001 - above(Trapeze type support Arrangement)	18	No. 3 or 4

Notes: All supports are considered at 2400 mm interval in above table and may vary as per the design but should not be greater than 2400mm.

All units shall be adequately secured and supported in an approved manner using wire hanger suspension Y fit solution as per manufacturers' recommendation with prior approval.

Rigid Supports to be used in conjunction with wire supports:

Rigid supports if required in conjunction with wire hangers shall be of steel, adjustable for height and Zinc chromate primer coated and finish coated black or H.D.Galvanised as per interior requirement. Where supports and clamps are of dissimilar materials, a gasket shall be provided in between. If the MS angle at the bottom if required as per design should be as per following table:

Longer size of Duct (mm)	**Type of Joints**
Up to 750	25x25x3 mm L angle with M8 nuts & bolts
751-1000	25x25x3 mm L angle with M8 nuts & bolts
1001-1500	40x40x5 mm L angle with M8 nuts & bolts
1501-2250	50x50x5 mm L angle with M10 nuts & bolts
2251 & above	50x50x6 mm L angle with M10 nuts & bolts

All the supporting system should be supplied from the same manufacturer.

Alternatively, ducts can be supported by means of threaded galvanised rods as per schedule given in standard installation detail drawings

f the sensor. And the accuracy shall be within 2.5% even with irregular duct approach.

6.15 Documentation & Measurements for Ducting

All ducts fabricated and installed should be accompanied and supported by proper documentation viz:

a) Bill of material/Packing list for every duct section supplied.

Measurement sheet covering each fabricated duct piece showing dimensions and external surface area along with summary of external surface area of duct gauge-wise.

Each and every duct piece to have a tag number, which should correspond to the serial number, assigned to it in the measurement sheet. The above system will ensure speedy and proper site measurement and verification.

Unless otherwise specified, measurements for ducting for the project shall be on the basis of centerline measurements described herewith:

Ductwork shall be measured on the basis of external surface area of ducts. Duct measurements shall be taken before application of the insulation. The external surface area shall be calculated by measuring the perimeter comprising overall width and depth, including the corner joints, in the center of each duct section, multiplying with the overall length from flange face to flange face of each duct section and adding up areas of all duct sections. Plenums shall also be measured in a similar manner.

For tapered rectangular ducts, the average width and depth shall be considered for perimeter, whereas for tapered circular ducts, the diameter of the section midway between large and small diameter shall be adopted, the length of tapered duct section shall be the centerline distance between the flanges of the duct section.

For special pieces like bends, tees, reducers, branches and collars, mode of measurement shall be identical to that described above using the length along the centerline.

The quoted unit rate for external surface of ducts shall include all wastage allowances, flanges and gaskets for joints, nuts and bolts, hangers and angles with double nuts for supports, rubber strip 5mm thick between duct and support, vibration isolator suspension where specified or required, inspection chamber/access panel, splitter damper with quadrant and lever for position indication, turning vanes, straightening

vanes, and all other accessories required to complete the duct installation as per the specifications. These accessories shall NOT be separately measured nor paid for.

b. Special Items for Air Distribution shall be measured by the cross-section area perpendicular to air flow, as identified herewith :

i. Grilles and registers - width multiplied by height, excluding flanges. Volume control dampers shall form part of the unit rate for registers and shall not be separately accounted.

ii. Diffusers - cross section area for air flow at discharge area, excluding flanges. Volume control dampers shall form part of unit rate for supply air diffusers and shall not be separately accounted.

iii. Linear diffusers - shall be measured by cross-sectional areas and shall exclude flanges for mounting of linear diffusers. The supply air plenum for linear diffusers shall be measured with ducting as described earlier.

iv. Fire dampers - shall be measured by their cross sectional area perpendicular to the direction of air flow. Quoted rates shall include the necessary collars and flanges for mounting, inspection pieces with access door, electrical actuators and panel. No special allowance shall be payable for extension of cross section outside the air stream.

v. Flexible connection - shall be measured by their cross sectional area perpendicular to the direction of air flow. Quoted rates shall include the necessary mounting arrangement, flanges, nuts and bolts and treated-for-fire requisite length of canvas cloth.

vi. Kitchen Hoods - shall be measured by their cross sectional area at the capture point of fumes, parallel to the surface of kitchen equipment. Quoted rates shall include the grease filters, provision for hood light, suspension arrangement for the hood, profile to direct the air to ventilation ducts and provision for removable drip tray.

6.16 Testing And Balancing

After the installation of the entire air distribution system is completed in all respects, all ducts shall be tested for air leaks by visual inspection.

The entire air distribution system shall be balanced using an anemometer. Measured air quantities at fan discharge and at various outlets shall be identical to or less/excess than 5 percent of those specified and quoted. Branch duct adjustments shall be permanently marked after air balancing is completed so that these can be restored to their correct position if disturbed at any time. Complete air balance report shall be submitted for scrutiny and approval, and four copies of the approved balance report shall be provided with completion documents.

7. INSULATION

7.1 Scope

The scopeofthissection comprisesthesupplyand application of insulation conforming to these specifications. The insulation material shall be Closed Cell Elastomeric Nitrile Rubber / Polyethylene Foam / EPDM

7.2 Material

Thermal insulationmaterialfor Duct & Pipe insulation shallbewith factory laminated black fiber glass cloth closed cell Elastomeric UV resistant. Thermal conductivity as per **BS 874 part 2 – 86 (DIN 52613 52612) /DIN EN 12667 / EN ISO8497** ofthe insulation material shall not exceed 0.018 W/m^{o}Kor0.212 BTU / (Hr-ft^{2}-^{o}F/inch) at an average temperature of 30^{o}C.Density of the nitrile rubber shall be 40-60 Kg/m^{3}, for EPDM shall be 40-60 Kg/m^{3}& for polyethylene material it shall be 25-30 Kg/m^{3}. The product shall have temperature range of –40 ^{o}C to 105^{o}C. The insulation materialshall befire rated for Class 0 as per BS 476 Part 6 : 1989 for fire propagation test and for Class 1 as per BS 476 Part 7, 1987 for surface spread of flame test.Water vapour permeability shall be not less than 0.024 per inch (2.48 x 10^{-13} Kg/m.s.Pa i.e. $\mu \geq 7000$: Water vapour diffusion resistance) as per **DIN 53122 part 2, DIN 52615 / EN 12086 & EN11469**.

In addition to above properties the insulation material for ducts shall be anti-microbial.Microbiological growth on insulation surface shall be in accordance with ASTM G-21 and bacterial resistance to ASTM2180.

The Material shall comply to ISO 5659 / BS 6853 / ABD 0031 for smoke density and toxicity values. The thermal conductivity of insulation material shall not be effected by aging as per **DIN 52616 standard.**

Insulation shall be with self-adhesive for ducting and piping and available in roles / sheets.

Thickness of the insulation shall be as specified for the individual application.**Each lot of insulation material delivered at site shall be accompanied with manufacturer's test certificate for density and thickness.** Samples of insulation material from each lot delivered at site may be selected by Owner's site representative and gotten tested for thermal conductivity and density at Contractor's cost.Adhesive used for sealing the insulation shall be non-flammable and with low VOC content (maximum 850 gm/l as per IGBC guide lines) strictly as per manufacturer's recommendations.

Ducting insulation thickness shall be as per table below.

Ducting position	**Thk. for non-coastal places**	**Thk. for coastal places**
SA duct in RA path	13 mm	19mm
Ducted return air system	SA duct: 19 mm RA duct: 13 mm	SA duct: 25 mm RA duct: 19 mm
Both SA & RA exposed	Both 25mm	Both 25 mm
SA duct having open cell nitrile rubber insulation	9 mm	9 mm

Anti-microbial duct insulation material thickness can be 1 mm less than corresponding standard nitrile rubber insulation.

7.3 Duct Insulation

Externalthermalinsulation shall beprovidedas follows :

The thickness of insulation material shall be as shown on drawings or identified in the schedule of quantity.Following procedure shall be adhered to:

Duct surfaces shall be cleaned to remove all grease, oil, dirt, etc. prior to carrying out insulation work.Measurement of surface dimensions shall be taken properly to cut closed cell insulation to size with sufficient allowance in dimension.Cutting of insulation sheets shall be done with adjustable blade to make 90^0 cut in thickness ofsheet.Hacksaw or blades are not acceptable tools for cutting the insulation.

Material shall be fitted under compression and no stretching of material shall be permitted. All longitudinal and transverse joints shall be sealed by providing 50 mm wide Fibre glasscloth laminated tape as per manufacturer recommendations. The insulation installers shall be certified by manufacture.

Where ducts/pipes penetrates walls / floor it shall be insulated with intumescent properties insulation material for fire protection. The treatment shall be minimum 500 mm extended on both sides.

7.4 Piping Insulation

All chilled water, refrigerant, and condensate drainpiping shallbeinsulated in the manner specifiedherein. Before applyinginsulation,all pipe shallbe brushedand cleaned.AllMS pipes shall be provided with a coat of zincchromate primer. Thermal insulation shall be applied as follows or as specified in drawings or schedule of quantity:

Piping Insulation thickness shall be as follows;

Pipe nominal bore	**Thk. for non-coastal places**	**Thk. for coastal places**
15 mm – 25mm	19 mm	25mm
12 mm – 80 mm	25 mm	12 mm
100 mm – 400 mm	12 mm	18 mm
Above 400 mm	45 mm	45 mm

Insulating material in tube form (minimum upto 100 dia pipes) shall be sleeved on the pipes.On piping, slit opened tube from insulating material shall be placed over the pipe and adhesive shall be applied as suggested by the manufacturer.Adhesive must be allowed to tack dry and then press surface firmly together starting from butt end and working towards centre.Wherever flat sheets shall be used it shall be with self-adhesive and cut out in correct dimension using correct tools.Scissors or Hacksaw-blade shall not be allowed. All longitudinal and transverse joints shall be sealed by providing 50 mm wide fiber glass cloth laminated tape as per manufacturer recommendations.The adhesive shall be strictly as recommended by the manufacturer. The insulation shall be continuous over the entire run of piping, fittings and valves.All valves, fittings, joints, strainers etc.in chilled water piping shall be insulated to the same thickness as specified for the main run of piping and application shall be same as above.Valves bonnet, yokes and spindles shall be insulated in such a manner as not to cause damage to insulation when the valve is used or serviced.

Direct contact between pipe and hanger shall be avoided. Hangers shall pass outside the saddle. Manufacturer shall supply PUF saddles with pre-laminated insulation sheet of both side (PUF saddle sandwich between insulation material on both side) so that the insulation material is joint with insulation material on both side (only for Nitrile & EPDM) and the weight of pipe is transferred to the PUF saddle in the center.

Manufacturer's installation manual shall be submitted and followed for full compliance.All insulation work shall be carried out by skilled workmen specially trained and certified by manufacturer in this kind of work.All insulated pipes shall be labeled (S.R. or R.R.) and provided with 300 mm wide band of paint along circumference at every 1200 mm for colour coding.Direction of fluid shall also be marked.Un-insulated MS pipes shall be painted throughout and direction of fluid marked.All painting shall be as per relevant BIS codes.

7.5 Protective Coating / Vapour Barrier Over Insulation

All ducts and pipes (On the roof / outside) exposed to UV rays shall be covered with two coats of UV paint / epoxy.

Alternate (Pipe Insulation Only)

"TF" Quality Expanded Polystyrene

All chilled water , refrigerant, and condensate drainpiping shallbeinsulated in the manner specifiedherein.Before applyinginsulation,all pipe work andfittingsshallbe brushedand cleaned, and dust, dirt, mortar and oil removed.AllMS pipes shall be provided with a coat of zincchromate primer,followedbytwo coatsofcoldsettingadhesive compound. Thermal insulation shall then be applied as follows :

Pipe size (mm)	Thickness for T F Quality expanded polystyrene mm
10to40	25
50to150	50
150 to 450	75
Above 450	100

Pre-molded pipe sections shall be placed over the pipes,the longitudinaland transversal jointsof these pipe sections shallbesealed with the adhesive compound. Theinsulationshallbe continuousovertheentire runofpiping,fittingsand valves.

Insulation shall be applied only after the piping systemhas been satisfactorily tested for leaks at 2 times the working pressure or at minimum 10 kg/sq.cm.testpressure.All insulatedpipes shall be covered withtwo layersof400 gage polythenesheetto act as vapour barrier. PVC straps at 400 mm centre shall be used to hold insulation andvapourbarrier together.Insulation shall becovered with26 gaugeGI sheetcladdingas per Schedule of Quantities andfinished in neat andcleanmannerso as to achieve true surface. All longitudinal and transversejoints inthe outer cladding shall have a minimum overlap of 50mm duly beaded and grooved and shall be sealed withelastomeric metalsealant 95-44 of Benjamin Foster USA,orequivalent.Use of screws for fastening may puncture vapour barrier hence GIbands 0.50mm thick x 25 mm wide shall beprovidedat every 500 mm to retaincladding in position.Adhesive component once opened shall be used immediately and no leftovers shall be permitted to be used following day.

Allinsulation work shall be carried out by skilledworkmen speciallytrained in this kind of work. Allinsulatedpipes shall be labeled (S, R or RR) andprovided with band of paintfor color coding as per IS codes.Direction of fluid shall alsobe marked.Un-insulated M S pipes shall bepaintedthroughoutand direction of fluid marked.All paintingshall be as per relevantBIScodes.

Insulated pipes exposed to UV rays shall be covered with fiberglass fabric. Over fabric one coat of fire proof or Epoxy acrylic compound shall be applied. The coat shall be allowed to cure to non – stick state. Subsequently second coat of compound shall be applied to givetough and smooth finish to the insulated surface.

7.6 Duct Acoustic Lining

Open Cell Nitrile Rubber

Duct acoustic lining materialshallbeNitrile Rubber open cell foam.Thermal conductivityofthe insulation material shall not exceed 0.047 W/m^{o}Kat an average temperature of 20^{o}C.Density of the nitrile rubber shall be 140 – 180Kg/m^{3}. The material should withstand maximum surface temperature of +85^{o}C and minimum surface temperature of -20^{o}C.The material should conform to Class 1 rating for surface spread of Flame in accordance to BS 476 Part 7 & HBF, HF 1 & HF 2 in accordance to UL 94, 1996.

Insulation should have antimicrobial product protection, and should pass Fungi Resistance as per ASTM G 21 and Bacterial Resistance as per ASTM E 2180.The insulation should pass Air Erosion Resistance Test in accordance to ASTM Standard C 1071-05 (section 12.7).

Thickness of the material shall be 15 mm thick specified for the individual application and with noise absorption proprieties as per IS: 8225 / ISO 154 / ASTM423C. The insulation should be installed as per manufacturer's recommendation.

Acoustic lining in Plenums especially for Air diffusion connected to slot diffusers shall have 12mm thick rigid board of fiberglass/mineral wool having density of 48 Kg/m3.

For Noise sensitive applications such as Auditoriums, recording studios, etc. the acoustic insulation material shall have properties as tabled below:

		Absorption Coefficient at Octave band centre Frequencies(Hz)						
Density	Thk. mm	125	250	500	1000	2000	4000	NRC
12Kg/ m^{3}	15	0.05	0.13	0.12	0.65	0.79	0.93	0.45
	25	0.29	0.45	0.77	1.0	0.93	0.96	0.8
48 Kg/ m^{3}	15	0.05	0.12	0.29	0.51	0.68	0.8	0.4
	25	0.16	0.12	0.82	1.02	1.05	1.0	0.8
	50	0.3	0.85	1.03	1.07	1.06	1.0	1.0

Wherever acoustic consultant is involved in the project, the above table shall be vetted by him.

7.7 Data Centre Floor Insulation

Floor of data centre shall be insulated with 19mm thick aluminum foil faced nitrile rubber / XLPE insulation as per specifications. 600mm x 600mm grid shall be made on the floor. (Insulation grid shall be of same size as of data centre floor grid). This grid shall be made from 19 mm wide 22G GIC-section. These C-sections shall be screwed to floor. Depth of screwing in to the floor shall not be more than 5mm. Sections of insulation shall be stuck to floor with self adhesive / adhesive solution as recommended by insulation manufacturer.

7.8 Acoustic Lining Of Mechanical Rooms

Open Cell Nitrile Rubber

Two walls and ceiling ofair conditioningplant room and air handling unit/ fan roomsmaybe provided with acoustic lining. Material shall be processed from Nitrile rubber open cell foam.

The material should be fibre free. The density of the same shall be 140-180 Kg/m^{3}. The material should have thermal conductivity not exceeding 0.05 W/Mk. The maximum surface temperature of material shall withstand is 105^{0}C. and minimum temp shall be -20^{0}C. Thickness shall be as specified. The material should confirm to class 1 rating for surface spread of flame as per BS 476 Part 7 & HBF, HF1 & FH 2 in accordance with UL 94, 1996. Thickness, if not specified, shall be considered as 20mm.

Surface shall be cleaned andtwo coats of adhesive recommended by the manufacturer should be applied on the walls. The foam sheets should be cut to required size and a layer of adhesive should also be applied to it. When it is tack dry it is stuck to the walls / ceiling.

All longitudinal and transfer joint shall be covered with 22 gauge 50 mm wide GI strip with screws..

Acoustic lining of walls shall be terminated approximately15cmabove the finishedfloortoprevent damagetoinsulationdue toaccidentalwater-loggingin plant/AHU / fan rooms.

7.10 Underdeck Insulation For Roof

Underdeck insulation shall be either of the following with density greater than or equal to 25 Kg/m^3& thermal conductivity of 0.21 Btu in/ft^2 hr^o F (at 24º C as per ASTM C-518).

i. 100mm thick TF Quality expanded polystyrene
ii. 100mm thick Closed cell elastomeric nitrile rubber
iii. 100mm thick EPDM
iv. 100mm thick XLPE
v. 50mm thick phenotherm (Thermal conductivity of 0.16 Btu in/ft^2 hr^o F (at 24º C as per ASTM C-518)

Underdeck surface of ceiling shall be cleaned and made dirt free. Insulation panels as mentioned above shall be pasted on this surface with black CPRX compound / SR 998 rubber adhesive. 10g wire net shall be tightened around insulation so as to avoid any kind of sagging. Ends of net shall be overlapping by at least 25mm. Overlaps shall be screwed with galvanised screws to avoid rusting.

7.11 Pump Insulation

Chilled water pump shall be insulated to the same thickness as the pipe to which they are connected and application shall be same as above.Care shall be taken to apply insulation in a manner as to allow the dismantling of pumps without damaging the insulation.

7.12 Shell Insulation

The chiller shells shall befactory insulated in accordance with the manufacturer'sstandards.

11.13 Cold Water And Expansion Tank Insulation

Coldwater tank, and chilled water expansion tank shall beinsulated asper manufacturer's standard.

7.14 Sound Attenuators

Attenuatorsshall be installed in ducts inaccordancewith requirements ofdrawingsand as includedinScheduleof Quantities.

Noise levels within conditioned spaces shall be not greater than those set out in schedule below:

a. Noise Level Design Criteria

S. No.	Area	Acceptable Noise Levels (NC)	
i.	Guest room or Suite	25-30	
ii.	Service Apartment	25-30	
iii.	Ball Room/Meeting Rooms	25-30	**To be reviewed on** project to project basis **e.g. for Hospital, Hotels, Offices, etc.**
iv.	Guest floor corridors	30-15	
v.	Restaurant / Staff Dining	40-45	
vi.	Health Club-Gym. Squash, Snooker	40-45	
vii.	Public Circulation.	40-45	
viii.	Back-of-the-house areas	40-45	

ix.	Offices	30-15
x.	Office Corridor	15-40

b. Attenuatorsshall be of steel construction with casings out of minimum 22 G galvanized steel. Acoustic fill shall be inert, non-hygroscopic, vermin proof, fibre glass of requireddensity adequately protected against corrosion andcoveredwith 26 gageperforated aluminium sheet. Attenuators shall be supplied complete with flanges.

c. Acousticperformance of the attenuators(netinsertion loss) shall meet or exceed the values listed below :

OCTAVE BAND CENTRE FREQUENCY HZ

	63	125	250	500	1K	2K	4K	8K
Insertion loss dB 900 mm long attenuators	2	7	12	19	23	23	18	11
Insertion loss dB 1500 mm long attenuators	6	10	18	30	42	14	23	14

d. Thepressuredropvalues ofthesilencersshallbe indicated for each duty.

e. Manufacturers shall submit a test certificate for acoustic and aerodynamic performance of the attenuators. Attenuators shall be tested in accordance with ACMAtest methods/BS4718and insertion loss andselfgenerated noiseforeach octave band and pressure dropshallbe stated in the schedule.

7.15 Measurement Of Insulation

Unless otherwise specified measurement for duct and pipe insulation for the project shall be on the basisof centre line measurements described herewith

a. Pipe Insulation shall be measured in unitsoflength along the centre line of the installed pipe, strictly on thesamebasisas thepipingmeasurementsdescribed earlier.The linear measurements shall betakenbefore theapplication of the insulation. It may be notedthat forpiping measurement, all valves, orificeplatesand strainers are not separately measurable by their number and size.Itistobe clearlyunderstood that for the insulation measurements, all these accessoriesincluding cladding,valves, orifice plates and strainers shall be consideredstrictlyby linearmeasurementsalongthe centrelineofpipesand nospecialrateshallbe applicable for insulation of any accessories, fixtures or fittings whatsoever.

b. DuctInsulation and Acoustic Lining shall bemeasured onthebasis of surface area along the centre line of insulation thickness. Thus the surface area of externally thermally insulated or acoustically linedbe basedontheperimetercomprisingcentreline (of thicknessofinsulation) width and depth ofthecross sectionofinsulated or lined duct, multipliedbythe centre-line length including tapered pieces, bends, tees, branches, etc. as measured for bare ducting.

8. ELECTRICAL INSTALLATION

13.1 Scope

The scope of this section comprises of fabrication, supply, erection, testing and commissioning of Motor Control Centre (MCC), wiring and earthing of all air-conditioning equipment, components and accessories.

Note – Configuration of MCC panels shall be design to suit the requirement of system \ process. Necessary single line diagrams \ GA drawings shall be furnished by contractor for approval by consultant \ owner.

13.2 General

Work shall be carried out in accordance with the accompanying specifications and shall comply with the latest relevant Indian Standards and Electricity Rules and Regulations.

All motor control centres shall be suitable for operationon 3 Phase/single phase, 11,000/415/240 volts, 50 cycles, 4 wire system with neutral grounded at transformer.All MCCsbe CPRI tested design and manufactured by a approved manufacturer. **CPRI certificatebe made available.**

MCCscomply with the latest Relevant Indian Standards andElectricityRules and Regulations and shallbe as per IS-8623. MCCs / starter panels for outdoor equipment shallbe suitable for outdoor duty application.

8.3 Constructional Features

The Motor Control Centre (MCC) shallbe of 2 mm thick sheet steelcabinet and suitable for indoor installation, dead front, floormounting/wall mounting type and shall be form 3b construction.The Distribution panelsbe totallyenclosed, completely dust and vermin proof andbewith hinged doors and folded covers, Neoprene gasket,padlocking arrangement and bolted back. All removable/ hinged doors and covers shall be groundedby flexible standard connectors.MCC shall be suitable for the climatic conditions as specified in Special Conditions. Steel sheets used in the construction of panelsbe 2 mm thick andbe folded and braced as necessary to provide a rigidsupport for all components.Joints of any kindinsheet metal shall beseam welded, all welding, slagshall berounded off and welding pits wiped smooth with plumber metal. The general constructionconfirm to IS-8623-1977 (Part-1) for factory built assembled switchgear & control gear for voltage upto and including 1100 V AC.

AllMCCs/panels and covers shall be properly fitted andsquarewith theframe, and holes in the panel correctlypositioned.Fixing screwsenter into holes tapped into an adequatethickness of metal or provided with wing nuts.Self-threading screwsnotbe used in the construction of Distribution panels.Abase channelof 75 mm x 40 mm x 5 mm thick shall be providedatthe bottomforfloor mounted panels.Minimum **operating** clearance of275mmbe provided between the floor of panelsand the lowest operating height.

The MCCshallbe of adequate size with a provision ofspare feeders. Feedersbe arranged in multi-tier. Knockoutholesof appropriate size and number shall be provided in the Motor Control Centre in conformity with the location of cable/conduitconnections.Removablesheet steel plates shall be providedatthe top to make holes for additional cable entry at site if required.

Every cabinet shall be provided with Trifoliate or engravedmetal nameplates.All panels shall be provided with circuitdiagram mounted on inside of door shutter protected with Hylam sheet. All live accessible connections shallbe shrouded andminimum clearance between phase and earthbe 20 mm and phase to phasebe 25 mm.

Panels with ACB shall necessarily have front and rear access as per requirement whereas panels with all MCCB breaker shall be provided with front access with sufficient clearance.

8.4 Wiring System

All control wiring shall be carried out by using PVC insulated copperconductor wiresin conduits.Minimumsizeofcontrol wiringbe1.5 sq mm.Minimumsizeof conductor for power wiring shall be4sq. mm 1100voltsgradePVC insulatedcopperconductorwiresin conduit. All conductors shall be stranded.

8.5 Circuit Compartment

All components for each feeder shall be housed in a separatecompartmentandhave steel sheets ontopand bottomof compartment.Sheet steel hinged lockable doorbedulyinterlocked with the breaker inthe"ON"position.Safety interlocksbe provided to prevent the breaker from being drawn-out when the breaker is in 'ON' position.The doornot form an integral part of the draw-out portion of the panel.Sheetsteel barriers shall beprovidedbetweenthe tiers in a vertical section.

All MCCs shall be provided with feeders of appropriate capacity as per Single Line Diagram. All MCCs shall be completely factory wired, ready for connection.Allthe terminals shall be of proper currentratingand sizedtosuit individual feeder requirements. Eachcircuitbe clearlynumbered fromleftto righttocorrespond with wiring diagram.All theswitchesand circuitsbe distinctly marked with a smalldescriptionof the service installed.

Continuous earth bus sized for prospective fault current shallbe provided with arrangement for connecting to station earth at two points. Hinged doors/ frames shall be connected to earth through adequately sized flexible braids.

8.6 Instrument Accommodation

Adequatespaceshallbeprovidedforaccommodatinginstruments, indicating lamps, control contactors and control MCBs. These shallbeaccessiblefortestingandmaintenance without any danger of accidental contact withlive parts of the circuit breaker and bus bar `ON' lamps shallbeprovided on all outgoing feeders.

8.7 Bus Bar Connections

Bus bar and interconnections shall be of high conductivity electrolytic grade aluminium/copper complying with requirement ofIS : 5082 – 1981 and of rectangular cross section suitable for carrying the rated fullload currentand short circuit current andshall beextendableon either side.Copper conductorshall be used for busbar of rating 1000A and above. Bus bars and interconnections shallbe insulatedwith heat shrinkable sleeve of 1.1 KV gradeandshall be colourcoded. Busbars shallbe supported on glass fiber reinforcedthermosetting plasticinsulated supports at regular intervals to withstand theforcearising from in case of short circuit inthesystem. Allbusbars shallbe provided in a separate chamber andallconnections shallbe done bybolting.Additionalcross sectionalarea to be added to the bus bar to compensateforthe holes. All connectionsbetween bus bars and breakers shall be through solidcopper / aluminium stripsof proper size to carry fullratedcurrentand insulated with insulating sleeves. Maximum current density for the busbarsbe 0.8 A/sq.mm for aluminium and 1.4 A/sq.mm for copper busbars.

Maximum allowable temperature for the Bus bar to be restricted to 85 deg C

8.8 Temperature - Rise Limit

Unless otherwise specified, in the case of external surface of enclosures of bus bar compartment which shall be accessible but do not need to be touched during normal operation, an increase in the temperature rise limits of 25° C above ambient temperaturebe permissible for metal surface and of 15° C above ambient temperature for insulating surfaces as per IS 8623(Part-2) 1993.

8.9 Cable Compartments

Cable compartment of adequate size shallbe providedinthe panel for easyclampingofall incomingandoutgoing cables entering fromthetop/bottom.Adequate supportsbe provided in cable compartment to support cables as per approved for construction shop drawing.

8.10 Air Circuit Breakers (Acb)

The ACBconform to the requirements of IEC 60947-2 / IS 8947-2 and shallbe type tested & certified for compliance to standards from–CPRI, ERDA/ any accredited international lab. The circuit breaker shallbe suitable for 415 V $\pm$ 10%, 50 Hz supply system.Air CircuitBreakersbe with moulded housing flush front, draw out type and shall be provided with a tripfree

manualoperating mechanismor as indicated in drawingswith mechanical "ON" "OFF"“TRIP” indications.

The ACBbe 3/ 4 pole with modular construction, draw out, manually or electrically operated version as specified.The circuit breakersshall be for continuous rating and service short Circuit Breaking capacity (Ics) shall be as specified on the single line diagram and should be equal to the Ultimate breaking capacity(Icu) and short circuit withstand values(Icw) for 1 sec.

Circuit breakers shallbe designed to ‘close'and `trip' withoutopeningthe circuit breaker compartmentdoor.The operating handle and the mechanical trip push button shall be atthefront of the breakers panel.Inspection of main contacts should be possible without using any tools. The ACB shallbe provided with a door interlock. i.e. door should not be open when circuit breaker is closed and breaker should not be closed when door is open.

Allcurrentcarrying parts shall be silver platedandsuitable arcingcontactswith proper arc chutesshall beprovidedto protect the main contacts. The ACBhave double insulation (Class-II) with moving and fixed contacts totally enclosed for enhanced safety and in accessibility to live parts. All electrical closing breakerbe with electrical motor wound stored energy spring closing mechanism with mechanical indicator to provide ON/OFF status of the ACB.

The auxiliary contacts blocksshall beso located as to be accessible from the front.Theauxiliary contacts in the trip circuitsclose before the main contacts haveclosed. All other contactsclosesimultaneouslywith themaincontacts. The auxiliary contacts in thetripcircuitsopen after the main contacts open.Minimum 4 NO and 4 NC auxiliary contactsbe provided on each breaker.

Rated insulation voltagebe 1000 volts AC.

8.10.1Cradle

The cradleshall be so designed and constructed as topermit smoothwithdrawal and insertion of the breaker into it.The movementsbe free from jerks, easy to operate andbe on steel balls/rollers and not on flat surfaces.

Thereshall be 4 distinct and separate position of thecircuit breaker on thecradle.
Racking Interlock in Connected/Test/Disconnected Position.

Service Position: Main Isolating contacts and control contacts of the breaker are engaged.

Test Position : Main Isolating contacts are isolated but control contacts are still engaged.

Isolated Position: Both main isolating and control contacts are isolated.

There shall be provision for locking the breaker in any or all of the first three positions.

The following safety featuresbe incorporated :

a. Withdrawal or engagement of Circuit breaker not be possible unless it is in open condition.

b. Operation of Circuit breakernot be possible unless it is fully in service, test or drawn out position.

c. All modules shall be provided with safety shutters operated automatically by movement of the carriage to cover exposed live parts when the module is withdrawn.

d. All Switchgear module front covershave provision for locking.

e. Switchgear operating handles shall be provided with arrangement for locking in 'OFF' position.

8.10.2 Protections

The breaker should be equipped with micro-controller based , communicable type release with RS 485 port for communication to offer accurate and versatile protection with complete flexibility andoffer complete over current protection to the electrical system in the following four zones :

- Long time protection.
- Short time protection with intentional delay.
- Instantaneous protection.
- Ground fault protection.

The protection releasegenerally have following features and settings **however for exact selection of protection releases shall be made based on project requirement,**

a. True RMS Sensing

The releasesample the current at the rate of 16 times per cycle to monitor the actual load current waveform flowing in the system andmonitor the true RMS value of the load current. Ittake into account the effect of harmonics also.

b. Thermal Memory

When the breaker reclose after tripping on overload, then the thermal stresses caused by the overload if not dissipated completely,get stored in the memory of the release and this thermal memoryensure reduced tripping time in case of subsequent overloads. Realistic Hot/Cold curvestake into account the integrated heating effects to offer closer protection to the system.

c. Defined time-current characteristics :

A variety of pick-up and time delay settings shall be available to define the current thresholds and the delays to be set independently for different protection zones thereby achieving a close-to-ideal protection curve.

d. Trip Indication

Individual fault indication for each type of fault should be provided by LEDs for faster fault diagnosis.

e. Self powered

The releasedraw its power from the main breaker CTs andrequire no external power supply for its operation.

f. Zone Selective Interlocking

The release shall be suitable for communication between breakers to enable zone selective interlocking. This feature shall be provided for both short circuit and ground fault protection zones to offer intelligent discrimination between breakers. This feature enables faster clearance of fault conditions, thereby reducing the thermal and dynamic stresses produced during fault conditions and thus minimises the damage to the system.To implement ZSI manufacturer should supply all related equipment like power supply, wiring etc.

On-Line change of settings should be possible. It should be possible to carry out testing of release without tripping the breaker.

g. The releasemeet the EMI / EMC requirements.

h. The setting rangeof release shall be generallyas follows :

	SETTING RANGE OF RELEASE	
Type of Protection	PICK-UP CURRENT	TIME DELAY
Long Time	0.4 to 1.0 times I_n (I_r) Steps : 0.4, 0.5, 0.55, 0.60, 0.65, 0.70, 0.75, 0.80, 0.85, 0.90, 0.95, 1.00. Operating Limit : 1.05 to 1.2 times I_r	0.5 to 30 sec at 6 I_r Steps 0.5,1, 2,4, 6, 8,12,18,24 and 30 secs Tolerance : Corresponding to ±10% of current.
Short Time	2 to 10 times I_r Steps : 2,3,4,5,6,7,8,9 & 10 Tolerance : ±10%	20 ms to 600 ms Steps 20,60,100,160,200,260,300 400,500 and 600 ms Tolerance : ±10% or 20ms whichever is higher
Instantaneous	2 to 12 times I_n Steps : 2,3,4,6,8,10,12 Tolerance : ±10%	
Ground Fault	0.2 to 0.6 time I_n Steps : 0.2,0.3,0.4,0.5,0.6 Tolerance : ±10%	100 ms to 400 ms Steps : 100,200,300,400ms Tolerance : ±10% or 20 ms whichever is higher.

All **incomer** ACBshave following additional protections other than mentioned above.

- Under and over voltage
- Under and over frequency
- Restricted Earth Fault protection
- Trip Circuit supervision with PS class CT's.
- Undercurrent, (for DG set only)
- Reverse power (for DG set only)
- Phase sequence reversal (for DG set only)
- Load shedding and reconnection thru programmable contacts.
- Release should display theContact wear indication.

The release should provide local indication of actual %age loading at any instant.The release should be able to communicate on MODBUS RTU protocol using inbuilt RS485/212/Ethernet port and shall be integral part of supply with trip unit. Parameters of the Protection Release should be changeable from Release as well as thru communication network. Release should have graphical LCD for display of power parameters. The release of incoming breakers should provide comprehensive meteringwith the following parameters

- Phase currents (running, avg & max) – All parameters in single window.
- Release should be able to capture short circuit current on which ACB has tripped. The last ten trips and alarms shall be stored in memory with the date & time stamping along with type of fault and alarm. The sensing CT Should be Rogowsky type with measurement precision of 1%.
- Release should be self powered .
- Release should havefacility to select different type of IDMTL protection(DT,SIT,VIT,EIT,HVF) for better co-ordination with HT Breaker/Fuse.
- Phase voltages (running, avg & max)
- Energy & power parameters (active, reactive and apparent)
- PF
- Frequency
- Maximum Demand (KVA & KW)
- Total Harmonics distortion

All **O/G** ACBshave following functions.

Protection

- The ACB control unitoffer the following protection functions as standard:
  Long-time (LT) protection with an adjustable current setting and time delay;
- Short-time (ST) protection with an adjustable pick-up and time delay;
- instantaneous (INST) protection with an adjustable pick-up and an OFF Position.
- Current and time delay settingbe indicated in amperes and seconds respectively On a digital display.
- Earth-fault protection with an adjustable pick-up and time delaybe provided if indicated on the appended single-line diagram.

Measurements

- An ammeter with a digital displayindicate the true rms values of the currents for each phase. Releaseacknowledge the current & time delay settings done by user on the LCD display.
- A LED bargraphsimultaneously display the load level on the three phases.
- A maximeterstore in memory and display the maximum current value observed since the last reset. The datacontinue to be stored and displayed even after opening of the circuit breaker.

8.10.3 Safety Features

I. The safety shutterprevent inadvertent contact with isolating contacts when breaker is withdrawn from the Cradle.

II. Itnot be possible to interchange two circuit breakers of two different thermal ratings. For Draw-out breakers, an arrangementbe provided to prevent rating mismatch between breaker and cradle.

III. There shall beprovision of positive earth connection between fixed and moving portion of the ACB either thru connector plug or sliding solid earth mechanism. Earthing bolts shall be provided on the cradle or body of fixed ACB.

IV. The incoming panel accommodating ACB shall be provided with indicating lamps for ON-OFF positions, digital voltmeter and ammeter of size not less than 96 mm x 96 mm, selector switches, MCB for protection circuit and measuring instrument circuits.

V. It shall be possible to bolt the draw out frame not only in connected position but also in TEST and DISCONNECTED position to prevent dislocation due to vibration and shocks.

VI. Draw out breakers should not close unless in distinct Service/Test/Isolated positions.

VII. The insulation material usedconform to Glow wire test as per IEC60695.

VIII. The ACBprovide in built electrical and mechanical anti-pumping.

IX. All EDO ACB`shave Ready to Close Contactto ensure that the ACB gets a command only when it is ready to close for applications of Remote Control, AMF, Synchronization and Auto Source Change Over Systems.

8.11 Moulded Case Circuit Breaker (Mccb)

The MCCB should be current limiting type with trip time of less than 10 msec under short circuit conditions. The MCCB should be either 3 or 4 poles. MCCBcomply with the requirements of the relevant standards IS13947 – Part 2/IEC 60947-2 and should have test certificates for Breaking capacities from independent test authorities CPRI / ERDA or any accredited international lab.

MCCBcomprise of Quick Make -break switching mechanism, arc extinguishing device and the tripping unitshall be contained in a compact, high strength, heat resistant, flame retardant, insulating moulded case with high withstand capability against thermal and mechanical stresses

The breaking capacity of MCCBbe as specified in the Drawings. The rated service breaking capacity (Ics) should be equal to rated ultimate breaking capacities (Icu).MCCBs for motor application should be selected in line with Type-2 Co-ordination as per IEC-60947-2, 1989/IS 13947-2. The breaker as supplied to meet IP54 degree of protection.

8.11.1 Current Limiting & Coordination

- The MCCBemploy maintenance free minimum let-through energies and capable of achieving discrimination up to the full short circuit capacity of the downstream MCCB.**The manufacturerprovide both the discrimination tables and let-through energy curves for all.**

Protection Functions

- MCCBs with ratings less than 100 Ashall be equipped with Thermal-magnetic (**adjustable** thermal for overload and **fixed** magnetic for short-circuit protection) trip units
- Microprocessor MCCBs with ratings 100A and above shall be equipped with microprocessor basedtrip units.
- Microprocessor and thermal-magnetic trip units shall be adjustable and it shall be possible to fit lead seals to prevent unauthorized access to the settings
- Microprocessor trip unitscomply with appendix F of IEC 60947-2 standard (measurement of RMS current values, electromagnetic compatibility, etc.)
- Protection settingsapply to all poles of circuit breaker.
- All Microprocessor componentswithstand temperatures up to 125 °C

8.11.2 Testing

a) Original test certificate of the MCCB as per IEC 60947-1 &2 or IS13947be furnished.
b) Pre-commissioning tests on the switch board panel incorporating the MCCB shall be done as per standard specifications.

8.11.3 Interlocking

Moulded, case circuit breakersbe provided with the following interlocking devices for interlocking the door of a switch board.

a) Handle interlock to prevent unnecessary manipulations of the breaker.

b)Door interlock to prevent the door being opened when the breaker is in ONposition.

c) Defeat-interlocking device to open the door even if the breaker is in ON position.

- The MCCB shall be current limiting type and comprise of quick make – Break switching mechanism.MCCBs shallbe capable of defined variable overload adjustment.All MCCBs rated 100 Amps and abovehave adjustable over load &short circuit pick-up .

- All MCCB with microprocessor basedrelease unit, the protectionbe adjustable Overload, Short circuit and earth fault protection with time delay.

The trip commandoverride all other commands.

8.12 Motor Protection Circuit Breaker (Mpcb)

Motor circuit breakersconform to the general recommendations of standard IEC 947 -1,2 and 4 (VDE 660, 0113 NF EN 60 947-1-2-4, BS 4752) and to standards UL 508 and CSA C22-2 N°14.

The devices shall be in utilization category A, conforming to IEC 947-2 and AC3 conforming to IEC 947-4.MPCBhave a rated operational and insulation voltage of 690V AC (50 Hz) and MPCB shallbe suitable for isolation conforming to standard IEC 60947-2 andhave a rated impulse withstand voltage (Uimp) of 6 kV. The motor circuit breakers shallbe designed to be mounted vertically or horizontally without de-rating.Power supplybe from the top or from the bottom. In order to ensure maximum safety, the contactsshall be isolated from other functions such as the operating mechanism, casing, releases, auxiliaries, etc, by high performance thermoplastic chambers. The operating mechanism of the motor circuit breakers must have snap action opening and closing with free tripping of the control devices. All the polesclose, open, and trip simultaneously. The motor circuit breakersaccept a padlocking device in the "isolated" position.

The motor circuit breakers shall be equipped with a "PUSH TO TRIP" device on the front enabling the correct operation of the mechanism and poles opening to be checked. The auxiliary contacts shall be front or side mounting, and both arrangementsbe possible. The front-mounting attachmentsnot change the breaker surface area. Depending on its mounting direction the single pole contact block could be NO or NC. All the electrical auxiliaries and accessories shall be equipped with terminal blocks and shall be plug-in type. The motor circuit breakershave a combination with the downstream contactor enabling the provision of a perfectly coordinated motor-starter. This combinationenable type 1 or type 2 co-ordination of the protective devices conforming to IEC 60947-4-1.Type 2 co-ordinationbe guaranteed by tables tested and certified by an official laboratory: LOVAG (or other official laboratory).The motor circuit breakers, depending on the type, could be equipped with a door-mounted operator whichallow the device setting. The motor circuit breakers shall be equipped with releases comprising a thermal element assuring overload protection and a magnetic element for short-circuit protection. In order to ensure safety and avoid unwanted tripping, the magnetic trip threshold (fixed)be factory set to an average value of 12 Ir.

All the elements of the motor circuit breakers shall be designated to enable operation at an ambient temperature of 60°C without derating. The thermal trips shall be adjustable on thefront by a rotary selector. The adjustment of the protection shall be simultaneous for all poles. Phase unbalance and phase loss detectionshall be available. Temperature compensation (-20°C to +60°C)

8.13 Miniature Circuit Breaker (MCB)

Miniature Circuit Breakercomply with IS-8810-1996/IEC898-1995. Miniature circuit breakers shall be quick make and break type for 240/415 VAC 50 Hz application with magnetic thermal release for over current and short circuit protection. The breaking capacitynot be less than 10 KA at 415 VAC. MCBs shall be DIN mounted. The MCB shall be Current Limiting type (Class-3). MCBs shall be classified (B,C,D ref IS standard) as per their Tripping Characteristic curves defined by the manufacturer. The MCBhave the minimum power loss (Watts) per pole defined as per the IS/IEC and the manufacturerpublish the values.MCBensure complete electrical isolation & downstream circuit or equipment when the MCB is switched OFF.

The housing shallbe heat resistant and having a high impact strength. The terminals shallbe protected against finger contact to IP20 Degree of protection. All DP, TP, TPN and 4 Pole miniature circuit breakershave a common trip bar independent to the external operating handle.

8.14 Painting

Allsheetsteelworkundergoaprocessof degreasing, pickling in acid, cold rinsing,phosphating, passivaiting(seven tank processing) and then painted with electrostatic paint (Powder coating). The shade of colour of panel inside/outside shallbe as indicated in datasheets &relevant BIS code.

8.15 Labels

Engraved PVC labels shall be provided on all incoming andoutgoingfeeder.Circuit diagram showing thearrangementsofthe circuit inside the control panelshallbe pastedon inside of the panel door and covered withtransparent plastic sheet.

8.16 Meters

i. All voltmeters and indicating lampsshall be throughMCB's.

ii. Meters and indicating instrumentsbe plugtype.

iii. All CT's connection for meters shallbe through Test Terminal Block (TTB).

iv. CT ratio and burdens shallbe as specified on the Single line diagram.

8.17 Current Transformers

Currenttransformersbe provided for Control panels carryingcurrentinexcess of 60 amps.Allphasebe providedwithcurrenttransformers of suitable VAburdenwith 5 amps secondaries for operation of associatedmetering.

The CTsconfirm to relevant Indian Standards. The design and construction shall be dry type, epoxy resin cast**,** robust to withstand thermal and dynamic stresses during short circuits.Metering CTs,have inbuilt busbar mounting arrangement. Secondary terminals of CTsbe brought out suitable to a terminal block whichbe easily accessible for testing and terminal connections. The secondary terminal should be covered with insulation cap/cover so that there should not be any possibility of touching the live terminal. The protection CTsbe of accuracy class 5P20 and measurement CTsbe of accuracy class I.

8.18 Selector Switch

Where called for, selector switchesof ratedcapacitybe provided in controlpanels,to give the choice of operating equipment in selective mode.

8.19 Contactor

Contactor shall be built into a high strength thermoplasticbody and shall be provided with an arc shield for quick arc extinguishing. Silver alloy tips shallbe provided to ensure a high degree of reliability and endurance under continuous operation. The magnet systemconsist of laminated yoke and armature to ensure clean operation without hum or chatter.

Starters contactorshave3 main and 2 Nos. NO /NC auxiliarycontacts and shall be air break typesuitable for making and breaking contact at minimum power factor of 0.15.For design consideration of contactors the starting current of connected motor shall be assumed to be 6times thefull load current of the motor in case ofdirect-on-linestartersand 3 times the full load currentofthe motorin case of Star Delta andReducedVoltageStarters.The insulation for contactor coilsbe of Class "E".

Coil shall be tape wound vacuum impregnated andbe housed in a thermostatic bobbin, suitable for tropical conditions andwithstand voltage fluctuations. Coilbe suitable for 220/415±10%volts AC, 50 cycles AC supply.

8.20 Thermal Overload Relay

Thermal over load relayhave built in phasefailure sensitive tripping mechanism to prevent against single phasing as well as on overloading. The relayoperate on the differential system of protection to safeguard against three phase overload, single phasing and unbalanced voltage conditions.

Auto-manual conversion facility shall be provided to convert from auto-reset mode to manual-reset mode and vice-versa at site. Ambient temperature compensation shall be provided for variation in ambient temperature from -5° C to +55°C.

All overload relays shall be ofthreeelement,positiveactingambienttemperature compensatedtimelaggedthermal over loadrelayswith adjustablesetting.Relays shall bedirectlyconnected formotorsupto 15 HP capacity.C.T.operatedrelaysbe provided for motors above 15 HP capacity.Heater circuitcontactsmaynot beprovidedwithoverload relays.

8.21 Time Delay Relays

Time delay relays shall beadjustable typewithtime delay adjustment from 0-180secondsandhave one set of auxiliary contacts forindicating lamp connection.

8.22 Indicating Lamp And Metering

All meters andindicating lampsbe in accordance with relevant IS standard specification.The meters shallbe flush mountedtype. The indicatinglampshallbeofLED type . EachMCC and controlpanelbe provided with voltmeter 0-500 volts with three way and off selector switch, CT operated ammeter of suitable range with threenos. CTS of suitable ratio with three wayandoff selectorswitch,phaseindicatinglamps,andother indicatinglampsas called for.Allindicating lampbebackedupwith5ampsMCB.

8.23 Toggle Switch

Toggle switches, where required,shall be in conformity with relevant IS Codes andbe of 5 amps rating.

8.24 Push Button Stations

Push buttonstationsshallbeprovidedformanual starting and stoppingofmotors/equipment Green and Red colour pushbuttonsshallbeprovidedfor‘Starting’and‘Stopping’ operations. ‘Start’ or ‘Stop’ indicating flaps shallbe provided for push buttons.Push Buttons shall be suitable forpanelmountingand accessiblefromfrontwithout opening door, Lock leverbe provided for ‘Stop’ push buttons.The push button contactsbe suitable for 6 amps current capacity.

8.25 Conduits

ConduitsandAccessoriesconformtolatest edition of Indian Standards IS-9517 part 1 & 2.16/14 (16 gauge upto 12mm diameter& 14 gauge above 12 mm diameter) gauge screwed GI or MS conduits to be used.Joints betweenconduitsand accessories shall be securely made by standard accessories, as per IS-2667, IS-1817 and IS-5113 to ensure earth continuity. All conduit accessories shall be threaded type only.

Only approved make of conduits and accessoriesbe used.

Conduitsshall be delivered to the site ofconstructionin originalbundles and each length of conduitbear thelabel of themanufacturer.

Note. : Whatever materials required to be billed by the Contractor should come on site with proper ChallanNumbers and quantity mentioned in each such Challan..

Maximum permissible number of1100 volt grade PVC insulated wires that may be drawn into metallic Conduits are given below :

Size of wires Nominal Cross section Area (Sq. mm.)	Maximum number of wires within conduit size(mm)				
	20	25	12	40	50
1.5	5	10	14	--	--
2.5	5	8	12	--	--
4	3	7	10	--	--
6	2	5	8	--	--
10	--	3	5	6	--
16	--	2	3	6	6
25	--	--	2	4	6
15	--	--	--	3	5

Maximum permissible number of1100 volt grade PVC insulated wires that may be drawn into rigid non metallic or PVC Conduits are given below :

Size of wires Nominal Cross section Area (Sq. mm.)	Maximum number of wires within conduit size(mm)				
	20	25	12	40	50
1.5	7	12	16	--	--
2.5	5	10	14	--	--
4	4	8	12	--	--
6	3	6	8	--	--
10	--	4	5	6	--
16	--	3	3	6	6
25	--	--	2	4	6
15	--	--	--	3	5

8.26 Cables

1100V grade Cables of sizes 25 sq. mm. and above shall be XLPE FRLS insulated aluminium conductor armoured type and PVC insulated Copper conductor armoured cables for sizes 16 sq. mm. and below. All cables shall be conforming to IS Codes. Cables shall be suitable for laying in trenches, ducts, and on cable trays as required.Cables shall be termite resistant. Cable glands shall be heavy duty double compression brass glands. Control cables and indicating panel cables shall be multi core PVC insulated copper conductor and armoured cables.

The equipment inside plant room shall be connected to the control panel by means of suitable cables of adequate size. An isolator shall be provided near each motor/equipment (mounted within 10 ~ 15 mtr distance on nearest wall or self-supported on floor) wherever the motor/equipment is separated from the supply panel through a partition barrier or through ceiling construction. PVC insulated copper conductor wires shall be used inside the control panel for connecting different components and all the wires inside the control panel shall be neatly dressed and plastic beads shall be provided at both the ends for easy identification of control wiring.

Cables shall be cross linked polyethylene (XLPE) insulated PVC inner sheathed and FRLS PVC outer sheath of 1100 volts grade.Cables shall be suitableforlayingintrenches,ducts, and on cable traysas required. Cables shallbe termite resistant.Cable glands shall be double compression glands. Controlcablesandindicating panel cables shallbe multi core PVCinsulated copper conductor and armoured cables. All conductors shall be stranded.

Cabling for following equipment shall be fire survival type.

1. Basement smoke exhaust fan
2. Jet fans
3. Smoke evacuation fan
4. Staircase, lift, lobby pressurization tank
5. Make-up air fan for emergency duty

8.27 Fire Survival Armoured Cable

Fire Survival armoured cable, LPCB / BRE-GLOBAL / ERDA approved, with class -2, annealed copper / or aluminum conductor having glass mica fire barrier tape extruded with cross linkable low smoke zero halogen insulation. The inner & outer sheath shall be LSZH. The basic design shall be as per BS: 7846 & BS: 5839-1 (Latest edition).

The cable should meet fire performance circuit integrity test as per BS 8414-2 / BS 6187 CWZ.

31.Power cabling shall be of the minimum following sizes:

i.	Upto 5 HP motors/ 5 KWheaters	3C x 4 sq. mm copper conductor PVC insulated cables.
ii.	From 6 HP to 10 HP motors 6 KW to 7.5 KW heaters	3 x 6 sq. mm copper conductor PVC insulated cables.
iii.	From 12.5 HP to 15 HP motors	2 Nos. 3 x 6 sq. mm copper conductor PVC insulated cables.
iv.	From 20 HP to 25 HP motors	2 Nos. 3 x 10 sq. mm copper conductor PVC insulated cables
v.	From 30 HP to 15 HP motors	2 nos. 3 x 16 sq. mm aluminium conductor armoured cable.
vi.	From 40 HP to 50 HP motors	2 Nos. 3 x 25 sq. mm. aluminium conductor armoured cable.
vii.	From 60 HP to 75 HP motors	1 No. 3 x 70 sq. mm aluminium conductor armoured cable.
viii.	100 HP motors	1 No. 3 x 150 sq. mm. aluminium conductor armoured cable
ix.	150 HP motor	1 No. 3 x 240 sq. mm. aluminium conductor armoured cable.
x.	250 HP motor	2 Nos. 3 x 240 sq. mm. aluminium conductor armoured cable.
xi.	400 HP motor	3 Nos. 3 x 240 sq. mm. aluminium conductor armoured cable.
xii.	600HPmotor	3 Nos. 3 x 400 sq. mm. aluminium conductor armoured cable.

HVAC contractor shall submit cable schedule for all equipment for approval.

8.28 Cable Laying

Cables shall be laid byskilledandexperienced workmenusingadequaterollers to minimizestretchingofthe cable.The cable drumsbe placed on jacks beforeunwinding thecable.Great care shall be exercised inlayingcablesto avoid forming kinks.

8.28.1 Laying of Cables on Cable Trays

The relative position of the cables, laid on thecable traybe preserved and the cablesnotcross each other.At all changes in direction in horizontal andvertical planes, the cable shall be bent smooth with a radius as recommended by the manufacturer's. Allcablesbe laid with minimum one diameter gap andshallbe clamped at every metre to the cable tray. Cablesbe taggedforidentificationwithaluminumtagandclamped properly at every 20M.Tagsbe provided at both ends and all changesin directions both sides of wall and floor crossings. All cablebe identified by embossing on the tag the size of the cable, place of origin and termination.

All cables passing through holes in floor or walls shall be sealed withfireretardantSealant and shallbepaintedwithfire retardantpaintupto one meter onall joints, terminationsand both sides of the wall crossings by "VIPER CABLE RETARD".

8.28.2 Laying of Cables in Ground

The width oftrenchforlaying singlecablebe minimum 150 mm.Where more than one cable is to be laid in horizontal formation, the width of the trenchbe workout by providing 200 mm gap between the cables, except where otherwise specified.There shall be clearance of 150 mm between the end cable and the side wall of the trench.The minimum depth of the cable trenchno to be less than 750 mm for single layer of cables.When the cables are laid in more than one tier the depth of the trench shallbe increased by 300 mm for each additional tier.

Excavation of trenches : Thetrenches shall be excavated in reasonably straight lines.Wherever there isa change in direction, suitable curvature shallbeprovided.Wheregradients and changes indepthareunavoidable, these shall be gradual.The excavated soil shall be stacked firmly by thesideofthe trench such that it may not fall back intothe trench.The bottom of the trench shall belevelledand shall be made free from stone, brick bats etc.The trenchthen shall be provided with a layer of clean, dry sand cushionof notless than 100 mm in depth. Prior to laying of cables, thecores shallbetestedfor continuityand insulation resistance.The cabledrumbe properly mounted on jacks,ata suitable location, making sure that thespindle, jack etc. are strong enough to carry the weight ofthedrum and the spindle is horizontal.Cableshallbepulledoverrollersinthe trenchsteadilyanduniformly withoutjerksand strains.The entiredrum lengthshall be laid in onestretch.However,where this is not possible theremainderof thecablebe removed by `Flaking' i.e.bymakingonelongloop in the reversedirection.Afterthecablehas been uncoiled and laid into the trenchover the rollers, the cable shallbe lifted offthe rollers beginningfrom one end by helpers standing about 10meters apart and laid in areasonablystraightline.Cable laid in trenches in a single tier formationhave a cover of clean, dry sand of not less than150 mm. above the base cushion of sand before the protectivecoveris laid.In thecaseofvertical multi-tierformationafter the first cablehasbeen laid,a sand cushion of 300 mm shall be providedovertheinitialbed before the second tier islaid.Finally the cablesbe protected by second class bricks before back filling the trench. The buried depth of uppermost layer of cablenot be less than 750mm.

Back Filling: The trenches shall be back filledwithexcavatedearth free from stones or othersharpedgeddebrisand shall be rammed and watered, ifnecessary,insuccessivelayersnot exceeding300 mm.Unlessotherwise specified, a crown of earth not less than50 mm in the centre and tapering towards the sides ofthe trench shall be left to allow for subsidence.

8.28.3 Wire And Wire Sizes

1100volts grade PVCinsultedcopperconductorwires in conduit shall be used.

For all single phase/ 3 phase wiring, 1100 volts grade PVC insulatedcopperconductorLSZH wiresshall be used. The equipmentinsideplantroomandAHUroomshallbe connected to the control panel bymeansofinsulated copperconductorwiresofadequatesizein exposed conduits.Finalconnections to the equipmentshallbe throughwiring enclosed in galvanizedflexibleconduits rigidlyclampedatboth ends and at regular intervals.Anisolatorshallbe provided near each motor/equipment wherever the motor/equipment is separated from the supply panel through a partition barrier or through ceiling construction.PVC insulated copper conductor wiresshallbe usedinsidethe control panel forconnectingdifferent componentsandall the wires insidethecontrolpanel shallbe neatly dressed and plasticbeads be providedatboththe ends for easy identification of control wiring.

The minimum size of control wiring shall be 1.5 sq. mmPVC insulated stranded soft drawn copper conductor wires drawn throughconduit to be provided forconnectingequipment and control panels.

Starters

Each motor shall be provided with a starterof suitablerating.Startersbe inaccordancewith relevantIS Codes.All Star Delta Startersbe fully automatic. **Motors up to 7.5 HPbe provided by Direct On Line (DOL) starter, motors above 7.5 HP and up to 45 HP shall be provided by star/delta starter and motors above 45 HP shall be provided by Automatic Star Delta / VFD**. All startersbe with Type II coordination for breaker, contactor and over load relay.

Alltheswitches,contactors,pushbuttonstations, indicatinglampsbe distinctly marked with asmall descriptionoftheserviceinstalled.Thefollowing capacity contactors and overload relaysshall beprovided fordifferentcapacity motors or aspermanufacturer's recommendation.

TYPE OF STARTER CAPACITY	CONTACTOR CURRENT	OVERLOAD RELAY RANGE
5HP Motors	D O L	16 amps 6-10amps
7.5 HP motors	D O L	16 amps 9-15amps
10HP Motors	Automatic Star Delta	25 amps 9-15amps
12.5 HP Motors	Automatic Star Delta	16 amps 9-15amps
15HP Motors	Automatic Star Delta	25 amps 9-15amps
20HP Motors	Automatic Star Delta	12 amps 14-23 amps
25HP Motors	Automatic Star Delta	12 amps 14-23 amps
30HP Motors	Automatic Star Delta	40 amps 20-13 amps
15HP Motors	Automatic Star Delta	40 amps 20-13 amps
40HP Motors	Automatic Star Delta	40 amps 30-50 amps
50HP Motors	Automatic Star Delta / VFD	70 amps 30-50 amps
60HP Motors	Automatic Star Delta / VFD	110 amps 30-50 amps
75HP Motors	Automatic Star Delta / VFD	110 amps 90-150 amps
100HP Motors	VFD	200 amps CT operated relay
125HP Motors	VFD	200 amps CT operated relay
150HP Motors	VFD	200 amps CT operated relay
150HP Motors	VFD	300 amps CT operated Relay.
200HP Motors	VFD	300 amps CT operated Relay.
250HP Motors	VFD	400 amps CT operated Relay.
300HP Motors	VFD	400 amps CT operated Relay.
400HP Motors	VFD	600 amps CT operated Relay.
600HP Motors	VFD	900 amps CT operated Relay.

Two speed motors when specified,be provided with DOL starter irrespective of it rating.

8.28.4 Cable Trays

Ladder and perforated type Cable Traysbe of Hot dip Galvanized type and factory fabricated out of CRCA sheet with standard accessories like tee, bends, couplers etc. for different loads and number and size of cables as given below :

Cable traysbe galvanized as per Specifications..

a. 1500 mm wide
Runners 25 x 100 x 25 x 3 mm
Rungs 2# 20 x 40 x 20 x 3 mm 250 mm C/C
Suspenders 2 Nos. 40 x 40 x 5 mm GI angle 1500 mm C/C with base support of 40x 40 x 5mm GI angle.

b. 1200 mm wide
Runners 25 x 100 x 25 x 3 mm
Rungs 2# 20 x 40 x 20 x 3 mm 250 mm C/C
Suspenders 2 Nos. 40 x 40 x 5 mm GI angle 1500 mm C/C with base support of 40x 40 x 5mm GI angle.

c. 1000 mm wide
Runners 25 x 100 x25 x 3 mm
Rungs 2# 20 x 40 x 20 x 3 mm 250 mm C/C
Suspenders 2 Nos. 40 x 40 x 5 mm GI angle 1500 mm C/C with base support of 40x 40 x 5mm GI angle.

d. 750 mm wide
Runners 20 x 75 x 20 x 2.5 mm
Rungs 20 x 30 x 20 x 2.5 mm 250 mm C/C
Suspenders 2 Nos. 12 x 12 x 5 mm GI angle 1800 mm C/C with base support of 40x 40 x 5mm GI angle.

e 600 mm wide
Runners 20 x 75 x 20 x 2.5 mm
Rungs 20 x 30 x 20 x 2.5 mm 250 mm C/C
Suspenders 2 Nos. 12 x 12 x 5 mm GI angle 1800 mm C/C with base support of 40x 40 x 5mm GI angle.

f. 450 mm wide
Runners 20 x 75 x 20 x 2.5 mm
Rungs 20 x 30 x 20 x 2.5 mm 250 mm C/C
Suspenders 2 Nos. 25 x 25 x 4 mm GI angle 1800 mm C/C with base support of 40x 40 x 5mm GI angle.

g. Supply and fixing of perforated type cable trays of the following sizes of pre-galvanized iron.

i. 600 x 40 x 40 x 2 mm thick
i. 450 x 40 x 40 x 2 mm thick
i. 300 x 40 x 40 x 2 mm thick
ii. 150 x 40 x 40 x 2 mm thick

Note : Suitable length of 10 mm dia GI rod suspenders at 1800 mm interval shall be included in the item for perforated type cable tray.

9. VARIABLE FREQUENCY DRIVES FOR HVAC SYSTEMS

9.1 General Requirements

9.1.1 This specification covers complete variable frequency drives (VFDs) designated on the drawing schedules to be variable speed. All standard and optional features shall be included within the VFD.

9.1.2 The frequency converter shall not be a general purpose product, but a dedicated HVAC engineered product.

9.1.3 The VFD and its options shall be factory mounted and tested as a single unit under full load before dispatch.

9.1.4 The VFD shall be tested to UL 508C. The appropriate UL label shall be applied.

9.1.5 The VFD shall be CE marked and conform to the European Union Electro Magnetic Compatibility directive.

9.1.6 The VFD shall be UL listed for a short circuit current rating of 100 kA and labeled with this rating.

9.2 Technical Requirements

9.2.1 The VFD shall convert incoming fixed frequency three-phase AC power into an adjustable frequency and voltage for controlling the speed of three-phase AC motors. The motor current shall closely approximate a sine wave. Motor voltage shall be varied with frequency to maintain desired motor magnetization current suitable for the driven load and to eliminate the need for motor de-rating.

VFD shall allow the motor to produce full rated power at rated motor voltage, current, and speed without using the motor's service factor. VFDs utilizing sine weighted/coded modulation (with or without 3rd harmonic injection) must provide data verifying that the motors will not draw more than full load current during full load and full speed operation.

9.2.2 The VFD shall include an input full-wave bridge rectifier and maintain a fundamental (displacement) power factor near unity regardless of speed or load.

9.2.3 VFD shall be with chokes / harmonic filters so as to maintain TH id as per (IEEE519, 1992) as indicated in Schedule of Quantity.

9.2.4 IEEE519, 1992 recommendations shall be used for the basis of calculation of total harmonic distortion (THD) at the point of common coupling (PCC). On request VFD manufacturer shall provide THD figures for the total connected load for project electrical single line diagram. Input information like transformer rating, impedance, short circuit current, short circuit impedance, cable sizes and lengths etc. shall be made available to VFD vendor. Cost of such analysis shall be included.

9.2.5 Unless specified otherwise, EMC Filters shall be provided (Integral or externally mounted) for all the Drive Ratings- Category **C2** EMC Filters for complete compliance with EN 61800-3 to confirm to both Conducted (minimum 75 metres) and Radiated Emissions (minimum 75 metres).

If asked for in schedule of quantities, VFDs shall contain EMC Filters (Integral or externally mounted) to attenuate Radio FrequencyInterference conducted to the AC power line to comply with the emission and immunity requirements of IEC 61800-3: 2004, Category **C1** with 50m motor cable (unrestricted distribution).

The suppliers of VFDs shall include additional EMC filters if required to meet compliance to this requirement.

9.2.6 The VFD's full load output current rating shall meet or exceed the normal rated currents of standard IEC induction motors. The VFD shall be able to provide full rated output current continuously, 110% of rated current for 60 seconds and 180% of rated torque for up to 0.5 second while starting.

9.2.7 The VFD shall provide full motor torque at any selected frequency from 20 Hz to base speed while providing a variable torque V/Hz output at reduced speed. This is to allow driving direct drive fans without high speed de-rating or low speed excessive magnetization, as would occur if a constant torque V/Hz curve was used at reduced speeds.Breakaway current of 160% shall be available.

9.2.8 A programmable flux optimization / Automatic energy optimization selection feature shall be provided as standard in the VFD. This feature shall automatically and continuously monitor the motor's speed and load to adjust the applied voltage to maximize energy savings.

9.2.9 The VFD must be able to produce full torque at low speed to operate direct driven fans.

9.2.10 Output power circuit switching shall be able to be accomplished without interlocks or damage to the VFD.

9.2.11 Motor Identification algorithm shall measure motor stator resistance and reactance to optimize performance and efficiency. It shall not be necessary to run the motor or de-couple the motor from the load to perform the test.

9.2.12 Galvanic isolation shall be provided between the VFD's power circuitry and control circuitry to ensure operator safety and to protect connected electronic control equipment from damage caused by voltage spikes, current surges, and ground loop currents. VFDs not including either galvanic or optical isolation on both analog I/O and discrete digital I/O shall include additional isolation modules.

9.2.13 VFD shall minimize the audible motor noise through the use of an adjustable carrier frequency. The carrier frequency shall be automatically adjusted to optimize motor and VFD operation while reducing motor noise. VFDs with fixed carrier frequency are not acceptable.

9.2.14 The VFD shall allow up to at least 100 meters of SWA (Single Wire Armour) cable to be used between the FC and the motor and allow the use of MICS (Mineral Insulated Copper Sheath) cable in the motor circuit for fire locations.

9.3 Protective Features

9.3.1 A minimum of Class 20 I^2t electronic motor overload protection for single motor applications shall be provided. Overload protection shall automatically compensate for changes in motor speed.

9.3.2 Protection against input transients, loss of AC line phase, output short circuit, output ground fault, over voltage, under voltage, VFD over temperature and motor over temperature. The VFD shall display all faults in plain language. Codes are not acceptable.

9.3.3 Protect VFD from input phase loss. The VFD should be able to protect itself from damage and indicate the phase loss condition. During an input phase loss condition, the VFD shall be able to be programmed to either trip off while displaying an alarm, issue a warning while running at reduced output capacity, or issue a warning while running at full commanded speed. This function is independent of which input power phase is lost.

9.3.4 Protect from under voltage. The VFD shall provide full rated output with an input voltage as low as 90% of the nominal. The VFD will continue to operate with reduced output, without faulting, with an input voltage as low as 70% of the nominal voltage.

9.3.5 VFD shall include current sensors on all three output phases to accurately measure motor current, protect the VFD from output short circuits, output ground faults, and act as a motor overload. If

an output phase loss is detected, the VFD will trip off and identify which of the output phases is low or lost.

9.3.6 If the temperature of the VFD's heat sink rises and approaches safe working temperature limit, the VFD shall automatically reduce its carrier frequency to reduce the heat sink temperature. It shall also be possible to program the VFD so that it reduces its output current limit value if the VFD's temperature becomes too high.

9.3.7 In order to ensure operation during periods of overload, it must be possible to program the VFD to automatically reduce its output current to a programmed value during periods of excessive load. This allows the VFD to continue to run the load without tripping.

9.3.8 The VFD shall have temperature controlled cooling fan(s) for quiet operation, minimized losses, and increased fan life. At low loads or low ambient temperatures, the fan(s) may be off even when the VFD is running.

9.3.9 Protect from output switching : The VFD shall be fully protected from switching a contactor / isolator at the output without causing tripping e.g.:for switching on/off the isolators of the AHU / ventilation fans / pumps near the motor with VFD in ON mode.

9.3.10 The VFD shall store in memory the last 10 alarms. A description of the alarm, and the date and time of the alarm shall be recorded.

9.3.11 When used with a pumping system, the VFD shall be able to detect no-flow situations, dry pump conditions, and operation off the end of the pump curve. It shall be programmable to take appropriate protective action when one of the above situations is detected.

9.4 Interface Features

9.4.1 Hand, Off and Auto keys shall be provided on the control panel to start and stop the VFD and determine the source of the speed reference. It shall be possible to either disable these keys or password protection them from undesired operation.

9.4.2 There shall be an "Info" key on the keypad.The Info key shall include "on-line" context sensitive assistance for programming and troubleshooting.

9.4.3 The VFD shall be programmable to provide a digital output signal to indicate whether the VFD is in Hand or Auto mode. This is to alert the Building Automation System whether the VFD is being controlled locally or by the Building Automation System.

9.4.4 Password protected keypad with alphanumeric, graphical, backlit display can be remotely mounted.

9.4.5 All VFDs shall have the same customer interface. The keypad and display shall be identical and interchangeable for all sizes of VFDs.

9.4.6 To set up multiple VFDs, it shall be possible to upload all setup parameters to the VFD's keypad, place that keypad on all other VFDs in turn and download the setup parameters to each VFD. To facilitate setting up VFDs of various sizes, it shall be possible to download from the keypad only size independent parameters. Keypad shall provide visual indication of copy status.

9.4.7 Display shall be programmable to communicate in English.

9.4.8 A red FAULT light and Green light for POWER ON shall be provided. These indications shall be visible both on the keypad and on the VFD when the keypad is removed.

9.4.9 A quick setup menu with factory preset typical HVAC parameters shall be provided on the VFD. The VFD shall also have individual Fan, Pump, and Compressor menus specifically designed to facilitate start-up of these applications.

9.4.10 VFD shall be provided with PID controller having feedbacks if indicated in schedule of quantity. This feature is to eliminate DDC panel by IBMS system vendor and use VFD itself as DDC. In such case, consultant can provide control scheme sketch to VFD manufacturer so that complete control system is fully configured in VFD.

9.4.11 This VFD shall be able to accept minimum 2 feedback signals. It shall be programmable to compare the feedback signals to a common set point or to individual set points and to automatically select either the maximum or minimum deviating signal as the controlling signal. It shall also be possible to calculate the controlling feedback signal as the average of all feedback signals or the difference between a pair of feedback signals.

9.4.12 The VFD shall be able to apply individual scaling to each feedback signal.

9.4.13 For fan flow tracking applications, the VFD shall be able to calculate the square root of any or all individual feedback signals so that a pressure sensor can be used to measure air flow.

9.4.9 The VFD's PID controller shall be able to actively adjust its setpoint based on flow. This allows the VFD to compensate for a pressure feedback sensor which is located near the output of the pump rather than out in the controlled system.

9.4.15 Floating point control interface shall be provided to increase/decrease speed in response to contact closures.

9.4.16 Five simultaneous meter displays shall be available. They shall be selectable from (at a minimum), frequency, motor current, motor voltage, VFD output power, VFD output energy, VFD temperature in degrees, feedback signals in their own units, among others.

9.4.17 Programmable Sleep Mode shall be able to stop the VFD. When its output frequency drops below set "sleep" level for a specified time, when an external contact commands that the VFD go into Sleep Mode, or when the VFD detects a no-flow situation, the VFD may be programmed to stop.When the VFD's speed is being controlled by its PID controller, it shall be possible to program a "wake-up" feedback value that will cause the VFD to start. To avoid excessive starting and stopping of the driven equipment, it shall be possible to program a minimum run time before sleep mode can be initiated and a minimum sleep time for the VFD.

9.4.18 A run permissive circuit shall be provided to accept a "system ready" signal to ensure that the VFD does not start until dampers or other auxiliary equipment are in the proper state for VFD operation. The run permissive circuit shall also be capable of initiating an output "run request" signal to indicate to the external equipment that the VFD has received a request to run.

9.4.19 VFD shall be programmable to display feedback signals in appropriate units, such as inches of water column (in-wg), pressure per square inch (psi) or temperature (°F). Examples can be room temperature in ^{0}C , return air temperature in ^{0}C , supply air temperature in ^{0}C,CO_2 concentration in ppm, pressure in bar, differential pressure in PSI etc.

9.4.20 VFD shall be programmable to sense the loss of load. The VFD shall be programmable to signal this condition via a keypad warning, relay output and/or over the serial communications bus. To ensure against nuisance indications, this feature must be based on motor torque, not current, and must include a proof timer to keep brief periods of no load from falsely triggering this indication.

9.4.21 Standard Control and Monitoring Inputs and Outputs

9.4.21.1 Four dedicated, programmable digital inputs shall be provided for interfacing with the systems control and safety interlock circuitry.

9.4.21.2 Two terminals shall be programmable to act as either as digital outputs or additionaldigital inputs.

9.4.21.3 Programmable relay outputs, 240V AC/2A shall be provided for remote indication ofVFD status. These shall be configured for Run, Alarm and Trip functions.

9.4.21.4 Each relay shall have an adjustable on delay / off delay time.

9.4.21.5 Two programmable analog inputs shall be provided that can be either direct-or-reverse acting.

9.4.21.6 Each shall be independently selectable to be used with either ananalog voltage or current signal.

9.4.21.7 The maximum and minimum range of each shall be able to be independently scalable from 0 to 10 V dc and 0 to 20 mA.

9.4.21.8 A programmable low-pass filter for either or both of the analog inputs must be included to compensate for noise.

9.4.21.9The VFD shall provide front panel meter displays programmable to show the value of each analog input signal for system set-up and troubleshooting,

9.4.21.10One programmable analog current output (0/4 to 20 mA) shall be provided for indication of VFD status. This output shall be programmable to show the reference or feedback signal supplied to the VFD and for VFD output frequency, current and power. It shall be possible to scale the minimum and maximum values of this output.

9.4.21.11It shall be possible to read the status of all analog and digital inputs of the VFD through serial bus communications.

9.4.21.12It shall be possible to command all digital and analog output through the serial communication bus.

9.4.22 Optional Control and Monitoring Inputs and Outputs

9.4.22.1 It shall be possible to add optional modules to the VFD in the field to expand its analog and digital inputs and outputs.

9.4.22.2 These modules shall use rigid connectors to plug into the VFD’s control card.

9.4.22.3 The VFD shall automatically recognize the option module after it is powered up. There shall be no need to manually configure the module.

9.4.22.4 Modules may include such items as:

9.4.22.5 Including relay outputs

9.4.22.6 Additional analog inputs, including Ni or Pt temperature sensor inputs

9.4.22.7 It shall be possible through serial bus communications to control the status of all optional 10.analog and digital outputs of the VFD.

9.4.23 Standard programmable firefighter's override mode allows a digital input to control the VFD and override all other local or remote commands. It shall be possible to program the VFD so that it will ignore most normal VFD safety circuits including motor overload. The VFD shall display FIREMODE whenever in firefighter's override mode.Firemode shall allow selection of forward or reverse operation and the selection of a speed source or preset speed, as required to accommodate local fire codes, standards and conditions.

9.4.24 A real-time clock shall be an integral part of the VFD.

9.4.24.1 It shall be possible to use this to display the current date and time on the VFD's display.

9.4.24.2 Ten programmable time periods, with individually selectable ON and OFF functions shall be available. The clock shall also be programmable to control start/stop functions, constant speeds, PID parameter set points and output relays. Is shall be possible to program unique events that occur only during normal work days, others that occur only on non-work days, and others that occur on specific days or dates. The manufacturer shall provide free PC-based software to set up the calendar for this schedule.

9.4.24.3 All VFD faults shall be time stamped to aid troubleshooting.

9.4.24.4 It shall be possible to program maintenance reminders based on date and time, VFD running hours, or VFD operating hours.

9.4.24.5 The real-time clock shall be able to time and date stamp all faults recorded in the VFD fault log.

9.4.24.6 The VFD shall be able to store load profile data to assist in analyzing the system demand and energy consumption over time.

9.4.24.6.1 The VFD shall include a sequential logic controller to provide advanced

9.4.24.6.2 Comparators for comparing VFD analog values to programmed trigger values

9.4.24.6.3 Logic operators to combine up to three logic expressions using Boolean algebra

9.4.24.6.4 Delay timers

9.4.24.6.5 A 20-step programmable structure

9.4.25 The VFD shall include a Cascade Controller which allows the VFD to operate inclosed loop set point (PID) control mode one motor at a controlled speed and controlthe operation of 3 additional constant speed motor starters.

9.5 Serial Communications

9.5.1 The VFD shall include a standard EIA-485 communications port and capabilities to be connected to the following serial communication protocols at no additional cost and without a need to install any additional hardware or software in the VFD:

Metasys N2
Modbus RTU

9.5.2 VFD shall have standard USB port for direct connection of Personal Computer (PC) to the VFD. The manufacturer shall provide no-charge PC software to allow complete setup and access of the VFD and logs of VFD operation through the USB port. It shall be possible to communicate to the VFD through this USB port without interrupting VFD communications to the building management system.

9.5.3 The VFD shall have provisions for an optional 24 V DC back-up power interface to power the VFD's control card. This is to allow the VFD to continue to communicate to the building automation system even if power to the VFD is lost.

9.6 Adjustments

9.6.1 The VFD shall have a manually adjustable carrier frequency that can be adjusted in 0.5 kHz increments to allow the user to select the desired operating characteristics. The VFD shall also be programmable to automatically reduce its carrier frequency to avoid tripping due to thermal loading.

9.6.2 Four independent setups shall be provided.

9.6.3 Four preset speeds per setup shall be provided for a total of 16.

9.6.4 Each setup shall have two programmable ramp up and ramp down times. Acceleration and deceleration ramp times shall be adjustable over the range from 1 to 3,600 seconds.

Each setup shall be programmable for a unique current limit value. If the output current from the VFD reaches this value, any further attempt to increase the current produced by the VFD will cause the VFD to reduce its output frequency to reduce the load on the VFD. If desired, it shall be possible to program a timer which will cause the VFD to trip off after a programmed time period.
If the VFD trips on one of the following conditions, the VFD shall be programmable for automatic or manual reset: external interlock, under-voltage, over-voltage, current limit, over temperature, and VFD overload.

The number of restart attempts shall be selectable from 0 through 20 or infinitely and the time between attempts shall be adjustable from 0 through 600 seconds.

An automatic "start delay" may be selected from 0 to 120 seconds. During this delay time, the VFD shall be programmable to either apply no voltage to the motor or apply a DC braking current if desired.

Four programmable critical frequency lockout ranges to prevent the VFD from operating the load at a speed that causes vibration in the driven equipment shall be provided.Semi-automatic setting of lockout ranges shall simplify the set-up.

9.7 Optional Features

9.7.1 All optional features shall be built and mounted by VFD manufacturer as an inbuilt factory solution. All optional features shall be UL listed by the VFD manufacturer as a complete assembly and carry a UL label.

9.8 Service Conditions

9.8.1 Ambient temperature at full speed, full load operation with continuous drive rated output current:

9.8.2 40^0C for all ratings upto 90 kW without derating

9.8.2 -10 to 40°C for ratings 110 kW and higher without derating

9.8.3 Relative Humidity:0 to 95%, non-condensing.

9.8.4 Elevation: Up to 3,300 feet without derating.

9.8.5 AC line voltage variation: ±10% of nominal with full output.

9.8.6 VFD protection: IP 54 or better

9.8.7 Side Clearances: No side clearance shall be required for cooling.

9.8.8 All power and control wiring shall be done from the bottom.

9.8.9 All VFDs shall be plenum rated.

9.9 Quality Assurance

9.9.1 To ensure quality, the complete VFD shall be tested by the manufacturer. The VFD shall drive a motor connected to a dynamometer at full load and speed and shall be cycled during the automated test procedure.

9.9.2 All optional features shall be functionally tested at the factory for proper operation.

10. QUALITY ASSURANCE,INSPECTION, TESTING AND COMMISSIONING

10.1 Scope

The following quality assurance, inspection, testing and commissioning procedures shall be required to be carried out upon award of work.

I. Provide quality assurance program (QAP), works quality assurance program (WQAP), field quality assurance program (FQAP) and quality plan.

II. Tests at manufacturer's works.

III. Perform site tests and commissioning.

10.2 Submittals

I. After award of work following information shall be submitted.

a. Quality Assurance Program (QAP)
b. Works Quality Assurance programme (WQAP)
c. Field Quality Assurance Programme (FQAP)

II. For inspection and testing, submit inspection and testing procedures, programme, record sheets applicable at each hold point.

III. After completion of testing, submit test records, packaging, transportation and storage instructions and methods.

IV. For site installation and commissioning, submit installation methods or procedures, notification and procedures for precommission and commissioning.

V. After commissioning, submit site test records, as-built drawings, manufacturer's operation maintenance manuals and list of recommended spares and tools.

10.3 Quality Assurance Concept And Control

I. Minimum requirements for establishing and implementing a quality assurance programme shall be applied to all aspects of the work necessary for carrying out the contract. Quality assurance shall extend to material parts, components, systems and services as a means of obtaining and sustaining the reliability of critical items, operating performance, maintenance and safety.

II. Acceptance of the Contractor's quality assurance programme does not relieve the Contractor's obligation to comply with the requirement of the contract document. If the programme is found to be ineffective, then the Owner's site representative reserves the right to request for necessary revisions of the programme.

III. The Contractor is required to produce readily identifiable documentary evidence covering the extent and details of both his own and his sub contractor's quality assurances system as follows :

a. Quality Assurance Program (QAP)
b. Works Quality Assurance programme (WQAP)
c. Field Quality Assurance Programme (FQAP)
d. Quality Plan.

IV. These documents shall be prepared separately and submitted to the Owner's site representative at the time ofstarting the work.

V. Quality Plan and Manual shall be prepared by the Contractor for all items and services to be supplied, after the contract has been placed, but before commencement of fabrication, and shall be subject to evaluation and acceptance by the Owner's site representative before start of work.

10.4 Quality Assurance Manual (Qam)

I. The QAM shall be a general comprehensive document outlining the Contractor's basic organization, policies and procedures. The information to be given in the QAM shall include but not limited to :

a. Quality Policy.

b. Quality Assurance Programme

c. Organisation Structure showing inter relationships.

d. Functional responsibilities and levels of authority.

e. Lines of communication.

f. Customer relations.

g. Laboratory Facilities.

10.5 Works Quality Assurance Programme (Wqap)

I. The WQAP shall identify the Contractor's Quality Assurance Programme at works applicable throughout all phases of Contract performance, including design, procurement, manufacture, inspection and testing. It shall identify each of the programme elements to be designed, developed, executed and maintained by the Contractor for the purpose of ensuring that all supplies and services comply with this specifications.

II. The information to be given under this programme shall include but not limited to :

a. Organisation and Responsibility.

b. Contract Review.

c. Design and Document Control.

d. Procurement Control.

e. Production Control.

f. Control on Sub-contractors.

g. In-process Quality Control and Traceability.

h. Inspection and Testing.

j. Control of Non-conformances.

k. Corrective Action.

l. Control of Inspection, Measuring and Test Equipment.

m. Handling, Storage, Packaging and Delivery.

n. Records.

p. Quality Audits.

q. After - Sales Servicing.

10.6 Field Quality Assurance Programme (Fqap)

I. This programme shall identify the Contractor's Quality Assurance Programme at site applicable throughout site construction, erection and commissioning. It is the underlying philosophy that the quality built into the product at works shall be maintained throughout the construction and commissioning stages.

II. While, in principle, the FQAP shall include the items discussed in WQAP, it shall, however, be approached differently to take into account site conditions.

III. The FQAP shall include, but not limited to the following information :

a. Organisation and responsibility.

b. Control of Drawings and Documentation.

c. Product Checklist.

d. Control and Traceability of Purchased materials and services.

e. Receipt Inspection of materials at site.

f. Material Storage Control.

g. Inspection and Examination Procedures.

h. Control of Painting and Insulation Works.

j. Pre-commissioning.

k. Commissioning.

l. Control of Non-conformances.

m. Corrective Action.

n. Control of Inspection, Measuring and TestEquipment.

p. Records.

q. Completion Documents.

r. List of recommended spares and tools.

s. Personal Training.

t. Servicing during Defects Liability Period.

10.7 Quality Plan

I. The contractor shall be required to prepare manufacturing and construction/erection quality plans for all equipment items and services. The quality plan shall also define the involvement of Owner's site representative in the inspection and test programmes.

II. The Quality Plan shall incorporate as appropriate :

a. Charts indicating flow of materials, parts and components through manufacturing quality control inspection and test to delivery and erection.

b. The charts shall indicate the location of hold points for quality control, inspection and test beyond which manufacture shall not continue until the action required by the hold point is met, and the documentation required is generated.

c. The control documents associated with each hold point, i.e. drawings, material, specification, Works Process Schedule (WPS), Process Quality Records (PQR), quality control methods and procedures and acceptance standards.

10.8 Site Quality Control Section

I. The Contractor's Quality Control (Q.C.) section shall be headed by an experienced Quality Control Engineer. He shall be assisted by other supervisors. The section shall be an independent one, reporting to the contractor's Site Manager only on administrative matters, but otherwise under full control by the Contractor's Corporate Quality System Management.

II. The Contractor's Q.C. Section shall liasise closely with the Owner's site representative in charge of Quality Assurance/Quality Control, and to whom it shall give fullest cooperation. It is the underlying principle of this contract document that while the Contractor's Q.C. Engineer implements the Contractor's Quality Programme, the adequacy and effectiveness of that implementation shall be audited by the Owner's site representative whose recommendations on improving or maintaining quality shall be acted upon promptly by the Contractor's Q.C. Section.

10.9 Inspection And Testing

I. All equipment and components supplied may be subjected to inspection and tests by the Consultant/ Owner's site representative during manufacture, erection/installation and after completion. The inspection and tests shall include but not be limited by the requirements of this contract document. Prior to inspection and testing, the equipment shall undergo pre-service cleaning and protection.

II. Tenderers shall state and guarantee the technical particulars listed in the Schedule of Technical Data. These guarantees and particulars shall be binding and shall not be varied without the written permission of the Owner's site representative.

III. No tolerances shall be allowed other than the tolerances specified or permitted in the relevant approved Standards, unless otherwise stated.

IV. If the guaranteed performance of any item of equipment is not met and / or if any item fails to comply with the specification requirement in any respect whatsoever at any stage of manufacture, test or erection, the Owner's site representative may reject the item, or defective component thereof, whichever he considers necessary; and after adjustment or modification as directed by the Owner's site representative, the contractor shall submit the item for further inspection and /or test.

V. The approval of the Owner's site representative of inspection and/or test results shall not prejudice the right of the Owner's site representative to reject an item of equipment if it does not comply with the contract document when erected, does notor prove completely satisfactory in service.

VI. The Contractor shall be responsible for the timely transmission of the relevant and appropriate sections of the contract document to manufacturers and sub-contractors for the proper execution of all tests at theirworks as per contract specifictions.

10.10 Tests At Manufacturer's Works

I. All tests to be performed during manufacture, fabrication and inspection shall be agreed with the Consultant/ Owner's site representative prior to commencement of the work. The Contractor shall prepare the details of the schedule and submit these to the Consultant/ Owner's site representative for approval. It must be ensured that adequate relevant information on the design code/standard employed, the manufacture /fabrication/assembly procedure and the attendant quality control steps proposed are made available to the Consultant/Owner's site representative who will mark in the appropriate spaces his intention to attend or waive the invited tests, or inspections.Contractor shall arrange inspection and factory witness test for centrifugal, screw chiller and vapour absorption chiller.

II. A minimum of twenty-one days' notice of the readiness of equipment for test or inspection shall be provided to the Owner's site representative by the Contractor (whether the tests be held at the Contractors of Sub-contractor's works). The subject items should remain available for Owner's site representative inspection and test up to a minimum 10 days beyond the agreed date of witnessing the test. Every facility in respect of access, drawings, instruments and manpower shall be provided by the Contractor and sub-contractor to enable the Owner's site representative to carry out the necessary inspection and testing of the Plant.

III. No plant shall be packed, prepared for shipment, or dismantled for the purpose of packing for shipment, unless it has been satisfactorily inspected, all tests called for have been successfully carried out in the presence of the Owner's site representative or approved for shipment, or alternatively inspection has been waived.

IV. Functional electrical, mechanical and hydraulic tests shall be carried out on completed assemblies in the works. The extent of these tests and method of recording the results shall be submitted to, and agreed by, the Owner's site representative in sufficient time to enable the tests to be satisfactorily witnesses, or if necessary for any changes required to the proposed programme of tests to be agreed.

V. The Consultant/Owner's site representative reserves the right to visit the Manufacturer's works at any reasonable time during fabrication of equipment and to familiarize himself with the progress made and the quantity of the work to date.

VI. Within 30 days of completion of any tests, triplicate sets of all principal test records, test certificates and correction and performance curves shall be supplied to the Owner's site representative.

VII. These test records, certificates and performance curves shall be supplied for all tests, whether or not they have been witnessed by the Owner's site representative or not. The information given on such test certificates and curves shall be sufficient to identify the

material or equipment to which the certificate refers and should also bear the Contract reference title.

VIII. When all equipment has been tested, the test certificates from all works and site tests shall be compiled by the Contractor into volumes and bound in an approved from complete with index and four copies of each volume shall be supplied to Consultant/ Owner's site representative.

IX. Stage wise inspection of equipment in factory in waived.

10.11 Performance Tests At Manufacturer's Woks

I. All equipment may be subjected to routine performance tests at the Manufacturer's Works in accordance with the relevant ANSI, ASME, ASTM, BIS standard including operating tests of complete assemblies to ensure correct operation of apparatus and components.

II. Pumps, fans, compressor, and other rotating equipment shall be given full load tests, and run to 15% over speed for 5 minutes to check vibration. Main and auxiliary gear boxes shall be subjected to shock load tests and a six-hour endurance run at rated speed and maximum torque.

III. The Contractor shall submit single line diagrams including the layout of the Plant together with the location of test instrumentation and the principal dimensions of the layout. All calculations to derive performance data shall be made strictly in accordance with format given in the approved standards. Any alterations or deviations from the approved standard test layout or formulae shall be subjected to the prior approval of the Owner's Site Representative.

IV. The performance test shall be conducted over the full operating range of the pump to a closed valve condition and a minimum of five measurement points covering the full range shall be taken. Curves indicating Quality vs. Head, Quantity vs. Power absorbed, and Quantity vs. Pump efficiency shall be provided. In addition a curve of the NPSH required vs. Quantity shall be provided except when the suction conditions do not require this test. Any proposal for the omission of this test shall be to the approval of the Consultant/ Owner's site representative.

V. On completion of the tests the Contractor shall submit a report showing the test results obtained together with the curves corrected to the site operating conditions.

11. TESTING, ADJUSTING AND BALANCING

11.1 Scope

a. Testing, adjusting and balancing of heating, ventilating and air-conditioning systems at site.

b. Testing, adjusting and balancing of HVAC Hydronic system at site.

c. Testing, adjusting and balancing of exhaust system at site.

Comply with current editions of all applicable practices, codes, methods of standards prepared by technical societies and associations including :

ASHRAE : 2011 HVAC Application.

SMACNA : Manual for the Balancing and Adjustment of air distribution system.

11.2 Performance

a. Verify design conformity.

b. Establish fluid flow rates, volumes and operating pressures.

c. Take electrical power readings for each motor.

d. Establish operating sound and vibration levels.

e. Adjust and balance to design parameters.

f. Record and report results as per the formats specified.

11.3 Definitions

a. Test : To determine quantitative performance of equipment.

b. Adjust patterns at : To regulate for specified fluid flow rates and air terminal equipment (e.g. reduce fan speed, throttling etc.)

c. Balance : To proportion within distribution system (sub mains, branches and terminals) in accordance with design quantities.

11.4 Testing, Adjusting and Balancing (Tab) Procedures

The following procedures shall be directly followed in TAB of the total system.

Before commencement of each one of the TAB procedure explained hereunder, the contractor shall intimate the PMC about his readiness to conduct the TAB procedures in the format given in these specifications.

11.5 Description Of System And Requirements

Adjust and balance the following system to provide most energy efficient operation compatible with selected operating conditions.

a. All supply, return and outside air systems.
b. All exhaust air systems.
c. All chilled water systems.
d. All cooling tower (condenser) water systems.
e. Emergency purge systems.

11.6 Air Systems

I. **Air Handlers Performance**

The TAB procedure shall establish the right selection and performance of the AHUs with the following results :

a. Air-IN DB and WB temperature.
b. Air-OUT DB and WB temperature.
c. Dew point air leaving.
d. Sensible heat flow.
e. Latent heat flow.
f. Sensible heat factor.
g. Fan air volume.
h. Fan air outlet velocity.
i. Fan static pressure.
j. Fan power consumption.
k. Fan speed.

II. **Air distribution**

Both supply and return air distribution for each AHU and for areas served by the AHU shall be determined and adjusted as necessary to providedesign air quantities. It shall cover balancing of air through main and branch ducts utilizing telescoping probes ofElectronic Rotating Vane Anemometers and Accubalance for grilles and diffusers.

III. **The Preparatory Work**

To conduct the above test, following preparatory works are required to be carried out including the availability of approved for construction shop drawings and submittals :

a. All outside air intake, return airand exhaust air dampers are in proper position.

b. All system volume dampers and fire dampers are in full open position.

c. All access doors are installed & are air tight.

d. Grilles are installed & dampers are fully open.

e. Provision and accessibility of usage of TAB instruments for traverse measurements are available.

f. All windows, doors are in position.

g. Duct system are of proper construction and are equipped with turning vanes and joints are sealed.

h. Test holes and plugs for ducting.

11.7 Hydronic System Balancing

I. The Hydronic system shall involve the checking and balancing of all water pumps, piping network (main & branches), the heat exchange equipment like cooling and heating coils, condensers and chillers and cooling towers in order to provide design water flows.

II. The essential preparation work, must be done by the HVAC contractor prior to actual testing, adjusting and balancing of HVAC system and ensure following :

- Availability of coordinated drawings and approved submittals and system sketch with design water flows specified thereon.
- Hydronic system is free of leaks,is hydrostatically tested and is thoroughly cleaned, flushed and refilled.
- Hydronic system is vented.

III. The contractor shall confirm completion of the basic procedures and prepare check lists for readiness of system balance.

a. Check pumps operation for proper rotation and motor current drawn etc.

b. Confirm that provisions for TAB measurements (Temperature, pressure and flow measurements) have been made.

c. Open all shut-off valves and automatic control valves to provide full flow through coils. Set all balancing valves in the present position, if these values are known. If not, shut all riser balancing valves except the one intended to be balanced first.

Balancing work for both Chilled Water System and Condenser Water System shall be carried out in a professional manner and test reports in the specified format shall be prepared and presented to the PMC/Consultants for approval.

11.8 Readiness For Commencement Of Tab

Before starting of any of the tests, the readiness to do so should be recorded as per the prescribed check list.

11.9 Tab Instruments

I. Air Measuring Instruments

a. For measuring DB and WB temperature, RH and dew point, microprocessor based TSI USA make VelociCalc Plus Meter, Model 8186, or equivalent shall be used.This instrument shall be capable of calculating the sensible, latenttotal heat flows, sensible heat factor and give printouts at site and have data logging/downloading facility.

b. For measuring Air velocity, DB temperature and Air volume, TSI USA makeVelociCalc meter model 8186/ 8145 or equivalent shall be used. It shall be able to provide instant print out of recorded Air volume readings.

c. Pitot tube.

d. Electronic Rotary Vane Anemometer TSI make or equivalent.

e. Accubalance Flow Measuring Hood TSI make or equivalent.

[All above instruments shall have a valid certification from a reputed testing institution.

II. Hydronic Measuring Instruments

a. For measurement of water flow across balancing valves, instruments as provided by the manufacturer of the valves specific to the type of valves shall be need.This shall include but not be limited to differential pressure manometers. Temperature shallbe measured using electric thermometers from thermo wells provided at strategic location by the HVAC contractor.

The water balancing shall be carried out being computer simulation program provided / certified by the balancing valve manufacturer.

III. Rotation Measuring Instrument

a. Electronic Digital Tachometer.

IV. Temperature & RH Measuring Instrument

a. TSI VelociCalc model 8186 / VelociCalc model 8145 or equivalent.

V. Electrical Measuring Devices

a. Clamp on Volt ammeter.
b. Continuity Meter.

VI. Vibration and Noise Levels

Vibration and alignment field measurements shall be taken for each circulating water pump, water chilling unit, air handling unit and fan driven by a motor over 10 HP. Readings shall include shaft alignment, equipment vibration, bearing housing vibration, and other test as directed by the PMC.

Sound level readings shall be taken at ten (10) locations in the building as selected by the PMC. The readings shall be taken on an Octave Band analyzer in a manner acceptable to him. The contractor shall submit test equipment data and reporting forms for review. In order to reduce the ambient noise level the readings shall be taken at night. All test shall be performed in the presence of PMC/Consultant.

SYSTEM READY TO BALANCE
CHECK LIST

	Ready		Date			Ready		Date
1. HVAC Units (AHU)	Yes	No.	Corrected			Yes	No.	Corrected
a)General					**e)Vibriation isolation**			
Louvers installed					Springs and compression			
Manual dampers open & locked					Base level and free			
Automatic dampers set properly								
Housing Construction-leakage					**2.Duct systems**			
Access doors-leakage					**a) General**			
Condensate drain piping and pan					Manual dampers open & locked			
Free from dirt and debris					Access doors closed and tight			
Nameplate data					Fire dampers open and accessible			
b)Filters					Terminal units open and set			
Type and size					Registers and diffusers open and set			
Number					Turning vanes in square elbows			
Clean					Provisions made for TAB measurements.			
Frame-Leakage					Systems installed as per plans.			
c)Coils (Hydronic)					Ductwork sealed as required			
Size and rows					**b)Architectural**			
Fin spacing and condition					Windows installed and closed.			
Obstructions and/ or debris					Doors closed as required.			
Airflow and direction					Ceiling plenums installed and sealed.			
Piping leakage					Access doors closed and tight			
Correct piping Connections and flow					Air shafts and openings as required			
Valves open or set								
Airvents or steam traps					**3. Pumps.**			
Provisions made for TAB measurements					**a)Motors.**			
d)Fans.					Rotation			
Rotation.					Lubrication			
Wheel clearance and balance					Alignment			
Bearing and motor lubrication					Set screws tight			
Drive alignment					Guards in place			
Belt t tension.					Tank level and controls.			
Drive set screws tight					Starters and disconnect switches			
Belt guard in place					Electrical service & connections.			
Flexible duct connector alignment					Nameplate data.			
Starters and disconnect switches								
Electrical service & connections.								
Nameplate data								

b) Piping					**5. Refrigeration Equipment**			
Correct flow					Crankcase heaters energized			
Correct connections					Operating controls and devices.			
Leakage					Safety controls and devices.			
Valves open or set					Valves open			
Strainer clean					Piping connections and flow			
Air vented					Flexible connectors			
Flexible connectors					Oil level and lubrication			
Provisions made for TAB measurements					Alignment and drives.			
c)Bases					Guards in place.			
Vibration isolation.					Vibration isolation.			
Grouting					Starters, contactors and disconnect switches.			
Leveling.					Electrical connectors.			
					Nameplate data.			
4. Hydronic equipment.								
a)Heat Exchangers/HW coil					**6.Hydronic Piping systems.**			
Correct flow and connections					Leak tested.			
Valves open or set					Fluid levels and make-up			
Airvents or steam traps					Relief or safety valves.			
Leakage					Compression tanks and air vents.			
Provisions made for TAB measurements					Steam traps and connections.			
Nameplate data.					Strainers clean			
b)Cooling towers					valves open or set			
Correct flow and connections.					Provisions made for TAB measurements.			
Valves open or set					Systems installed as per plans.			
Leakage								
Provisions made for TAB measurements					**7.Controls System**			
Sump water level.					Data centers.			
Spray nozzles.					Outdoor return air reset			
Fan/pump rotation.					Economizer			
Motor/fan lubrication.					Static pressure			
Drives and alignment					Room controls.			
Guards in place.					**8.Other Checks.**			
					a)Other trades or personnel notified of TAB work requirements.			
					b)Preliminary data complete			
					c)Test report forms prepared.			

INSTRUMENT CALIBRATION REPORT

PROJECT _____

INSTRUMENT / SERIAL NO.	APPLICATION	DATES OF USE	CALIBRATION TEST DATE.

REMARKS.

TESTDATE _____ READINGS BY _____

AIR HANDLING EQUIPMENT TEST REPORT

PROJECT_____ SYSTEM / UNIT_____

LOCATION_____

UNIT	DATA		MOTOR	DATA
Make/Model No.			Make / Frame	
Type/Size			H.P / RPM	
Serial Number			Volts/Phase/cycles	
Arr./Class			F.L amps.	
Discharge			Pully Diam/Bore	
Pully diam/Bore			Pully/Distance.	
No. Belts/make/size				
No.Filters/type.size (Pre.)				
No.Filters/type/size (secondary)				

TEST DATA	DESIGN	ACTUAL		TEST DATA	DESIGN	ACTUAL
Total Cfm				Discharge S.P		
Total S.P						
Fan RPM				Cooling Coil S.P		
Motor Volts. $T_1T_2T_2T_3$ T_3T_1				Filters S.P		
Outside air Cfm						
Return air Cfm						

REMARKS.

TEST DATE_____READINGS BY _____

COOLING / HEATINGTEST REPORT (AHU)

PROJECT _____

COIL DATA	**COIL NO.**	**COIL NO.**	**COIL NO.**	**COIL NO.**
System Number				
Location				
Coil Type				
No. Rows Fins/In				
Manufacturer				
Model Number				
Face Area, Sq.Ft.				

TEST DATA	**DESIGN**	**ACTUAL**	**DESIGN**	**ACTUAL**	**DESIGN**	**ACTUAL**	**DESIGN**	**ACTUAL**
Air Qty. CFM								
Air Vel.FPM								
Press.Drop In.								
Out.Air DB/WB								
Ret. Air DB/WB								
Ent.Air DB/WB								
Lvg.Air DB/WB								
AirAT								
Waer flow. GPM								
Press.Drop.PSI								
Ent.Water Temp								
Lvg .Water Temp								
Water AT								
Exp.Valve/Refrig								
Refrig.Suction Pr.								
Refrig.Suct.Temp								
Inlet Steam press.								

REMARKS.

TEST DATE _____ READINGS BY _____

HOT FAN TEST REPORT

PROJECT_____

FANDATA	FANNO.	FAN NO.	FAN NO.
Location			
Service			
Manufacturer			
Model No.			
Serial No.			
Type / Class			
Motor Make / Style			
Motor H.P/RPM/ Frame			
Volts/Phase/Cycles			
F.L Amps.			
Motor pully Diam./Bore			
Fan pully Diam./Bore			
No. Belts/ Make/Size			
Pully Distance.			

TEST DATA	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL
CFM						
FAN RPM						
S.P IN/OUT						
TOTAL S.P						
Voltage$^{T_1T_2T_2T_3}_{T_3T_1}$						
Amperage$T_1T_2T_3$						

REMARKS:

TEST DATE:_____ READINGS BY _____

RECTANGULAR DUCT
TRAVERSE REPORT

PROJECT_____SYSTEM_____

LOCATION / ZONE_____ACTUAL AIR TEMP. _____DUCT S.P_____

DUCT	REQUIRED	ACTUAL
SIZE_____SQ.FT._____	FPM_____CFM_____	FPM_____CFM_____

POSITION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1															
2															
3															
4															
5															
6															
7															
8															
9															
10															
11															
12															
13															
VEL1OCITY SUBTOTALS															

REMARKS.

TESTDATE_____ READINGS BY _____

GRILLES AND DIFFUSERS
TEST REPORT.

PROJECT_____ SYSTEM _____

OUTLET MANUFACTURER_____TESTAPPARATUS_____

AREA	OUT LET			DESIGN		PRLIMINARY				FINAL		
SERVED	NO.	TYPE	SIZE	CFM	VEL	VEL OR CFM	VEL. OR CFM			VEL	CFM	

REMARKS.

TESTDATE_____READINGS BY _____

12. PAINTING AND FINISHES

12.1 Scope

The scope of this section comprises of colour scheme required for each piece of equipment

12.2 Colour Scheme.

Description	Standard Colour & Reference	Lettering Colouring
Exposed Duct Work (other than plant room) instruction	To Architect's	
Air Conditioning Duct Work (Plant Rooms)	BSS 111 Pale Blue	Black
Ventilation Duct Duct Work (Plant Rooms)	BSS 111 Pale Blue	Black
Conditioner Casings, Air Handling Units, Filter Plenums	BSS 111 Pale Blue	Black
Electrical (Conduit Ducts and Motors)	BSS 557 Light Orange	Black
Chilled Water Pipe	Jade Green	Black
Drains	Black	White
Vents	White	Black
Fans	BSS 111 Pale Blue	Black
Valves and Pipe Line Fittings	White with black handles	Black
Beltquards	Black and yellow diagonal stripes (45 25 mm wide)	
Switchboards - exterior - interior	BS 166 Light Beige White	
Machine Bases, Inertia Bases and Plinths	Charcoal Grey	

13. IDENTIFICATION OF SERVICES

13.1 Scope

The scope of this section comprises of identification of services for each piece of equipment

13.2 Valve Labels and Charts

Each valve shall be provided with a label indicating the service being controlled, together with a reference number corresponding with that shown on the Valve Charts and " as fitted" drawings.The labels shall be made from 3 ply (black / white/ black) Traffolyte material showing white letters and figures on a black background.Labels to be tied to each valve with chromium plated linked chain.

A wall mounted, glass covered plan to the approval of the Architect / Engineer shall be provided and desplayed in each plant room showing the plant layout with pipe work, valve diagram and valve schedule indicating size, service, duty, etc.

13.3 Identification Of Services.

Pipe work and duct work shall be identified by colour bands 150 mm. wide or colour triangles of at least 150 mm. / side.The bands of triangles shall be applied at termination points, junctions, entries and exits of plant rooms, walls and ducts, and control points to readily identify the service, but spacing shall not exceed 4.0 metres.

13.3.1 Pipe work Services :-

For pipe work services and its insulation the colours of the bands shall comply with BS. 1710: 1971.

Basic colours for pipe lineidentification :

Pipe Line Contents	**BS. 4800 Colour Reference**	**Colour.**
Water	12 D 45	Green
Steam	10 A 03	Grey
Oils	06 C 39	Brown
Gas	08 C 15	Yellow / Brown
Air	20 E 51	Blue
Drainage	00 E 53	Black
Electrical	06 E 51	Orange

Colour code indicator bands shall be applied as colour bands over the basic identification colour in the various combinations as listed below :-

Pipe Line Contents	Colour Bands to BS. 4800
Water Services :	
Cooling	00 E 55
Fresh / drinking	18 E 53
Boiler feed	04 D 45/00 E 55 / 04 D 45
Condensate	04 D 45/14 E 53 / 04 D 45
Chilled	00 D 55/14 E 53 / 00 D 45
Central Heating Services :	
Below 100^{o} C	18 E 55/04 D 45/18 E 53
Above 100^{o} C	04 D 45/18 E 53 /04 D 45
Cold Water Storage Tanks :	00 E 55/18 E 53/00 E 55

Hot Water Supply	00 E 55/04 D 45/00 E 55
Hydraulic Power	04 C 13
Sea / River Untreated	Basic Colour only
Fire Extinguishing	04 E 53
Steam Services :	Basic Colour only
Air: Compressed	Basic Colour only
Vacuum	White.
Town Gas : Manufactured	14 E 53
Natural	10 E 53
Oils :	
Diesel	00 E 55
Lubricating	14 E 53
Hydraulic Power	04 C 53
Transformer	04 D 45
Drainage and other fluids :	Basic Colour only
Electrical Services :	Basic Colour only

In addition to the colour bands specified above all pipe work shall be legibly marked with black or white letters to indicate the type of service and the direction of flow, identified as follows :-

High Temperature Hot Water	HTHW
Medium Temperature Hot Water	MTHW
Low Temperature Hot Water	LTHW
Chilled Water	CHW
Condenser Water	CONDW
Steam	ST
Condensate	CN

Pipe shall have the letters F and R added to indicate flow and return respectively as well as directional arrows.

13.3.2 Duct Work Services :

For Duct workservices and its insulation the colours of the triangles shall comply with BS.1710 : 1971.The size of the symbol will depend on the size of the duct and the viewing distance but the minimum size should not be less than 150 mm. length per side.One apex of the triangle shall point in the direction of airflow.

Services	**Colour**	**BS.4800 Colour Reference**
Conditioned Air	Red and Blue	04 E 53 / 18 E 53
Ward Air	Yellow	10 E 53
Fresh Air	Green	14 E 53

Exhaust / Extract / Recirculated Air	Grey	AA 0 09
Foul Air	Brown	06 C 39
Dual Duct System Hot Supply Air	Red	04 E 53
Cold Supply Air	Blue	18 E 53

In addition to the colour triangles specified above all duct work shall be legibly marked with black or white letters to indicate the type of service, identified as follows :-

Supply Air	S
Return Air	R
Fresh Air	F
Exhaust Air	E

The colour banding and triangles shall be manufactured from self-adhesive cellulose tape, laminated with a layer of transparent ethyl cellulose tape.

14. NOISE CONTROL

14.1 Scope

The scope of this section comprises of the supply, installation, testing and commissioning of noise and vibration control equipment and accessories.

14.2 Standards

The testing of all noise control equipment and the methods used in measuring the noise rating of air conditioning plant and equipment shall be in accordance with the relevant sections of the following British Standards, unless otherwise stated :

BS 4718 : 1971	Methods of Test of Silencers for Air Distribution Systems.
BS 2750 : Parts 1-9:1980	Laboratory and Field Measurement of Airborne Sound Insulation of Various Building Elements. Recommendations for Field Laboratory Measurement of Airborne and Impact Sound Transmission in Buildings.
BS 1618 : 1987	Methods of Measurement of Sound Adsorption in a Reverberation Room.
BS 4773 : Part 2: 1976	Acoustic Testing.
BS 4856 : Part 2: 1976	Acoustic performance without additional ducting of forced fan convection equipment.
Part 5: 1976	Acoustic performance with additional ducting of forced fan convection equipment.
BS 4857 : Par 2:1978 (1983)	Acoustic Testing and Rating of High Pressure Terminal Reheat Units.
BS 4954 : Par 2:1978 (1987)	Acoustic Testing and Rating ofInduction Units.
BS 5643 : 1984	Glossary of Refrigeration, Heating, Ventilating and Air Conditioning Terms.

14.3 General

Mechanical services shall generally be designed and installed with provisions to contain noise and the transmission of vibration, generated by moving plant and equipment at source where illustrated on the tender drawings and plant and equipment schedules to achieve acceptable noise rating specified for occupied areas.

In addition to the provisions specified in the Specification, particular attention must be given to the following details at time of ordering plant and equipment and their installation :-

a. All moving plant , machinery and apparatus shall be statically and dynamically balanced at manufacturers works and certificates issued.

b. The isolation of moving plant, machinery and apparatus including lines equipment from the building structure.

c. Where duct work and pipe work services pass through walls, floors and ceilings, or where supported shall be surrounded with a resilient acoustic absorbing material to prevent contact with the structure and minimise the outbreak of noise from plant rooms.

d. The reduction of noise breakout from plant rooms and the selection of externally mounted equipment and plant to meet ambient noise level requirements ofthe Specifications.

e. Electrical conduits and connections to all moving plant and equipment shall be carried out in flexible conduit and cables to prevent the transmission of vibration to the structure and nullify the provisions of anti-vibration mountings.

f. All duct connections to fans shall incorporate flexible connections, except in cases where these are fitted integral within air handling units.

Duct work connections to the fan inlets / outlets shall be concentricity aligned so that the flexible connections are not subjected to any strain and not used as a means of correcting bas misalignment.

g. All resilient acoustic absorbing materials shall be non flammable, vermin and rot proof and shall not tend to break up or compress sufficiently to transmit vibration or noise from the equipment to the structure.

h. Where practicable, silencers shall be built into walls and floors to prevent the flanking of noise the duct work systems and their penetrations sealed in the manner previously described.

Where this is not feasible, the exposed surface of the duct work between the silencer and the wall subjected to noise infiltration shall be acoustically clad as specified.

i. Contractor to demonstrate design NC levels in the areas with FFT (Fast Fourier Transform) analyzer.

14.4 Silencers

At tender stage all silencers as scheduled in the specification or on tender drawings will be selected based on preliminary sound power levels obtained from fan/air handling unit manufacturers or fan duties to achieve a noise rating in the occupied space as specified in " Basis of Design"

All plant attenuators shall be selected to maintain noise criteria given in this Specification.

Attenuators shall be constructed from high quality pre-galvanised steel sheet casings with lock formed joints along the casing length.Angle iron cross jointing flanges shall be fitted to silencer casings, drilled as required and finished with zinc cromet primer paint.

Acoustic splitters shall be formed by chancel section pre-galvanised sheet steel framework retaining acoustic fill of a density to attain the required performance.Splitters shall have round nose ends to give smooth entry and exit conditions to minimise air pressure drops.

The acoustic fill shall be protected from the air flow by 22 swg minimum perforated galvanised sheet steel.

All silencers shall be selected against a maximum allowable air pressure drop of 75 a.

It will be the responsibility of the Contractor at the time of placing orders for fan equipment to obtain from the manufacturers, certified sound power levels to enable the selected duct silencers to be checked against the original design information, prior to orders being placed.

14.5 Anti-Vibration Mountings.

All items of rotating and reciprocating plant and equipmentshall be isolated from the structure by the use of anti-vibration materials, mountings or spring loaded supports fixed to either concrete bases, inertia blocks or support steels as indicated.

Centrifugal fans and motors within air handling units shall be isolated from the frame of the air handling unit by suitable anti-vibration mountings.Fan discharge air connections shall be fitted with approved flexible connections internally isolating the fan scroll from the air handling unit casing.

Axial flow fans shall be mounted on steel legs as diaphragm plates supported on neoprene in shear anti-vibration mountings, or suspended using spring loaded hangers to suite the application.

Centrifugal pumps shall be mounted on inertia bases consisting of reinforced concrete sub-base, anti-vibration mountings and concrete filled steel upper plinth.The Contractor shall be responsible for issuing the steel upper plinth and mountings to the Contractor for building-in.

Pipe work connections to circulating pumps, chillers, cooler coils and other equipment shall be made with flexible connections as per Specifications.

The construction of the anti-vibration mountings shall generally comply with thefollowing : -

Enclosed Spring Mounting (Caged or Restrained Springs)

Each mounting shall consist of cast or fabricated telescopic top and bottom housing enclosing one or more helical steel springs as the principle isolation elements, and shall incorporate a built-in levelling device.

The springs shall have an outside diameter of not less than 75% of the operating height, and be selected to have at least 50% overload capacity before becoming coil bound.

The bottom plate of each mounting shall have bonded to it a neoprene pad designed to attenuate any high frequency energy transmitted by the springs.

Mountings incorporating snubbers of restraining devices shall be designed so that the snubbing damping or restraining mechanism, is capable f being adjusted to have no significant effect during the normal running of the isolated machine.

Restrained isolator shall be provided on chillers subject to approval by the manufacturers.

14.6 Open Spring Mountings.

Each mounting shall consist of one or more helical steel springs as the principal isolation elements, and shall incorporate a built-in leveling device.The spring shall be fixed or otherwise securely located to cast or fabricated top and bottom plates, and shall have an outside diameter of not less than 75% of the operating height, and shall be selected to have at least 50% overload capacity before becoming coil-bound.

The bottom plate shall have bonded to it a neoprene pad designed to attenuate any high frequency energy transmitted by the springs.

14.7 Neoprene-In-Shear Mountings.

Each mounting shall consist of a steel top plate and base plate completely embedded in oil resistant neoprene.Each mounting shall be capable of being fitted with a levelling device, and bolt holes in the base plate and tapped holes in the top plate so that they may be bolted to the floor and equipment where required.

14.8 Inertia Bases For Pumps.

The inertia base shall be an all welded mild steel channel frame the minimum depth of which shall be $^{1}/_{12}$of the longest span between isolator but not less than 150 mm. filled with concrete the density of which shall be 2300 kg/m^3.

The inertia base shall be sufficiently large to provide support for all parts of the equipment, including any component which overhang the equipment base, such as suction and discharge elbows on centrifugal pumps.

The frame shall include pre-located equipment anchor bolts fixed into position and housed in a steel sleeve allowing minor bolt location adjustment.

Isolator support brackets shall be welded into the corners of the base and suitably re-enforced for the load of the equipment and base.

Additional reinforcing roads shall be provided at 200 mm. centres to ensure the concrete and frame is adequately stiffened against distortion.

14.9 Flexible Connections

Flexible connections shall be provided on all duct work connections to fans, rotating plant and equipment isolated from structure and anti-vibration materials or mountings.Pipe work and duct work crossing building movement or construction joints shall be installed with flexible connections.

Flexible connections on duct work to fans etc., shall be a minimum / maximum free length of 100 mm. / 200 mm. respectively to minimise noise transmission and noise breakout.They shall be completely free from stress and shall not be required to accept any weight.

Thickness and strength of flexible connection materials shall be suitable to withstand the positive and negative fan pressures to which they will be subjected to and shall not allow perceptible leakage.The materials shall be durable, non flammable having food acoustical quality.

Flexible connections shall be fitted to all pump suction and discharge connections, chillers and other vibrating equipment and where anti-vibration mounts and inertia basis are fitted.

Flexible connections shall be fitted to all cooler coil chilled water pipe work connections.

Flexible connections shall allow freedom of movement of plant in all plans.

Making flanges to pipe work flexible connections shall be of the smooth faced weld-nick type.

Rubber Bellows shall be fitted as close to the source of vibration at practicable.The pipe at the other end of the bellows shall be a fixed point.

Rubber bellows shall be single convolution of multiply reinforced EPDM rubber with wire reinforced cuffs.Flanges shall be able to swivel and be removable. The date of manufacture shall be moulded on the bellows. For traceability membranes shall have an indelible identification showing manufacturer, country of origin, the type and a batch number.

Tie bars with rubber top hat washers shall be used on bellows.

For working temperatures up to 70° C the rubber bellows shall be high tensile synthetic fibre reinforced.

For working temperature between 70°C and 100°C the bellows carcase shall be steel wire mesh reinforced throughout.Steel reinforced bellows shall be manufactured and approved to the Standards.

For temperatures above 100°C bellow shall be multiply stainless steel with Van Stone ends swivel flanges.The overall length shall not exceed 130 mm.

Flexible connections with screwed connections shall be reinforced EPDM rubber hoses and shall have at least one full union to avoid torturing on installation.

Flexible pipe connections on chilled water systems shall be suitable for a working pressure of 10 bar and test pressure of 17 bar.

15.HVAC SYSTEMS APPROVED MAKES

Description	Manufacturer
Split Unit (3 Star as per BEE) / Ductable unit	Hitachi / Toshiba / Daikin / Samsung / LG
VRF	Daikin / Toshiba / Hitachi / Samsung / LG
AHU/ CSU	Zeco / VTS / Systemair / Citizen / Edgetech / Caryaire
Refrigerant Pipe	Mandev / Mehta Tubes / Nissan / Rajco / Mexflow
UPVC Pipes	Supreme / Astral / Finolex
Nitrile rubber insulation Thernal / Acoustic	Armaflex / Aeroflex / K-flex / AFLEX
Adhesives (non-flammable)	Armaflex 520 / Pidilite SR 998 / Foster IIDL
Ventilation Fans (Circular / Cabinet / Mixed flow inline)	Kruger / Nicotra / Systemair / Greenheck / Flaktwood / Caryaire
Propeller Fan (Non metal construction)	CG / Havells / Bajaj / Usha / Khaitan
Propeller fans (Metal construction)	Kruger / Nicotra / Marathon / CG / Dynair
Ducting	Ductofab / Vedha / Dev Duct / Seven star / Alpha duct / Zeco / Rolastar
GI Ducting sheet	SAIL / Jindal / TATA / Lloyd
Fire retardant flexible duct connector	Easy flex / Mapro / Resistoflex
Air terminals - Grille / Diffusers etc	Ruskin / Caryair / Cosmos / Dynacraft / Systaimair / Air product
VCD, NRD, Collar dampers & ancillaries	Ruskin / Caryair / Cosmos / Dynacraft / Systaimair / Air product
Fire dampers	Ruskin / Caryair / Cosmos / Dynacraft / Systaimair / Air product
Damper Actuators	Seimens / JCI / Honeywell
Anchor Fasteners	Hilti / Fischer / Mungo
Duct supports	Diamond / Hitech / Seven star / Hira
Fire paint	Birla 3 M / Flamebar / Hilti / Promat
Fire Sealent	Promat / Birla 3M / Hilti
Braided wire rope Supports	Gripple / HILTI / Mupro
Power & Control cabling	Polycab / KEI / RPG / Finolex
Cable Tray	Profab / Indiana / Asiana