

PROJECT IMPLEMENTATION UNIT GANDHINAGAR



TECHNICAL SPECIFICATIONS OF HVAC SYSTEMS

**Name of Work: - New Construction of 30 Bedded Community Health Center
at.Thangadh, Ta.Thangadh, Dist.Surendranagar.**

**Project Implementation Unit
4th Floor, PIU/RDD/NHM Building, Civil
HospitalCompound, Sector-12,
Gandhinagar –382 012.**

TECHNICAL SPECIFICATIONS

SECTION: I WATER COOLED CENTRIFUGAL CHILLING MACHINE WITH VFD.

1. SCOPE

The scope shall include but not limited to the following:

- a. CENTRIFUGAL chillers with positive pressure refrigerant R134-A ONLY with associated motors, automatic star-delta, soft starter, VFD and accessories.
- b. All associated items herein to be supplied delivered and installed.
- c. Manufacture, supply & assembly of chiller components including connection of coolers, condensers, motors, compressors, purge system for low pressure machine and all associated items.
- d. Manufacturer's factory representative's services, including coordination, start-up, testing and commissioning supervision.
- e. Testing at factory and project site, training and providing necessary documentation and tools for operation.
- f. Performance test run at site.

2. QUALITY ASSURANCE PROGRAM

- a. Water chilling machine shall be rated in accordance with Parameters indicated in Schedule of Quantities. Vessels shall be designed, constructed, tested, stamped and complete with devices in accordance with ASME Code, ANSI/ASHRAE 15-1989 Safety Code.
- b. The water chilling machine shall be the product manufactured / assembled of single service / works.
- c. The water chilling machine shall be designed/manufactured and tested in accordance with the applicable portions of the latest revisions of the following Standards and Codes.

ARI 550 / 590 - 2003 - Air Conditioning and Refrigeration Institute Performance rating of water chilling packages using the vapor compression cycle.

ARI 575 - Air Conditioning and Refrigeration Institute Standard Method of Measuring Machinery Sound within Equipment Rooms (Base of all data presented or field testing of equipment with relation to sound requirements).

ASME CODE - American Society of Mechanical Engineers Code for Unfired Pressure Vessels - Section VIII (Design, construction, testing and certification of pressure vessels).

ANSI-B9.1 - American National Standards Institute. Safety Code for Mechanical Refrigeration (overall general safety requirements, relief device sizing, etc.)

ANSI-B31.5 - American National Standards Institute. Code for Refrigerant Piping.

ISO R281 - Rolling Bearings – Dynamic Load Ratings and Rating for Life.

3. CAPACITY

Refrigeration capacity of water chilling machine shall be as shown on Drawings and indicated in Schedule of Quantities.

4. COMPRESSOR

Compressor shall be open / semi-hermetic direct / gear drive with integrated lubrication system through compressor pressure differential / oil pump. Compressor casing shall be constructed from a high strength iron casting, having reinforced double wall construction to provide a rigid structure and minimize the transmission of noise. Multiple pressure lubricated rolling element bearing shall be used to absorb axial thrust as well as radial load. Minimum 80 mesh reinforced SS strainer shall be provided at the suction of compressor for protection. Rotors shall be precision made from ductile iron.

Oil separator shall be provided at discharge side of compressor. Oil separator can be an integral part of compressor or alternatively, it could be separate pressure vessel. Oil separator shall contain impingement plate, removable SS oil strainer and electrical oil heater. Drained oil from oil separator shall be piped back to the compressor.

Step less capacity control to exactly match system load shall be provided. A microprocessor based controller shall modulate slide valve in response to chilled water outlet temp. Controller shall be programmed for PID&T logic. Compressor shall be able to unload up to 10% of load with stable running.

5. MICRO COMPUTER CONTROL CENTRE

Each unit shall be furnished with factory mounted, wired and tested microcomputer control Centre in a locked enclosure. The control center shall include a 40-character alphanumeric display showing all system parameters in English language with numeric data in English (FPS) units.

Digital programming of essential set points through a color coded, tactile-feel keypad shall include: entering and leaving chilled water temperature and condensing water temperature; percent loading; pull down demand limiting; seven-day time clock for starting and stopping chiller (complete with local holiday schedule); and remote reset temperature range.

All safety and cycling shutdowns shall be annunciated through the alphanumeric display and consist of day, time, cause of shutdown, and type of restart required. Safety shutdowns shall include: high oil pressure; high compressor discharge temperature; low evaporator pressure; motor controller fault; and sensor malfunctions. Cycling shutdowns shall include: low water temperature; low oil temperature; chiller/condenser water flow interruption; power fault; internal time clock; and entire cycle.

System operating information shall include: return/leaving chilled water temperatures; return/leaving condenser water temperatures; evaporator /condenser refrigerant pressure; differential oil pressure; percent motor current; evaporator/condenser saturation temperatures; operating hours (Hours Run) and number of compressor starts.

Security access shall be provided to prevent unauthorized change of set points to allow local or remote control of the chiller, and to allow manual operation of the pre-rotation vanes and oil pump. The chiller shall be provided with an RS-232 port to output all system operating data, shutdown/cycling messages and a record of the last four cycling or safety shutdowns to a remote printer or Building Automation System (BAS). The control center shall be programmable to provide data logs to the BAS/printer at a set time interval.

Control center shall be able to interface with the Building Automation System (BAS) to provide remote chiller start/stop reset of chilled water temperature reset of current limit; and status messages indicating chiller is ready to start, chiller is operating, chiller is shut down on a safety requiring reset, and chiller is shut down on a recycling safety.

6 INTERFACE WITH BAS

All necessary hardware / software to integrate the chiller panel to BAS system shall be provided free of cost by chiller manufacturer / supplier. Control panel should be with open protocol like Mudbugs RTU/ Banat/ Lon work to integrate with BAS.

For the integration of Microprocessor Panel of the chilling machine with the Building Automation System, an Interface Control Document shall be developed by BAS Contractor. It shall be responsibility of HVAC Contractor / Manufacturer to provide following to BAS Contractor to prepare the interface.

- a. Software Protocol of Chiller Microprocessor panel.
- b. Hardware Protocol of Chiller Microprocessor panel.
- c. Communication structure relating to collection of message / event information.
- d. Description of the formatted packets / blocks of data which construct controller commands / responses.
- e. Written permission to BAS contractor to develop the interface without any financial implication.

7 MOTOR

Motor shall be energy efficient and suitable for $415 \pm 10\%$ volts, 3 phases, and 50 cycles AC supply with VFD. Hermetic/semi hermetic motors shall be suction gas cooled, two pole, squirrel cage induction type. In case of open type compressor, motors shall be screen protected drip proof (SPDP) squirrel cage induction type. Motor shall be designed and guaranteed for continuous operation. Insulation of motors shall be 'B' class. Temperature rise of motor under rated service conditions shall not exceed 80 Deg C (by resistance method of measurement) over an ambient of 50 Deg C. the motor shall be provided with a combination of ball or roller bearing. Starting current shall not exceed 2 times of full load current at rated voltage and frequency. Terminal box shall be of sturdy construction and shall provide enough space for connecting PVC - insulated aluminum conductor cable. All terminal boxes shall have terminal suitable for cable glands of the specified cables.

The efficiency and power factor shall be not less than the following values, at rated voltage and frequency and at the specified loads.

| Load | Efficiency | Power Factor |
|---------------|------------|--------------|
| Full Load | 96% | 0.95 |
| $\frac{3}{4}$ | 96% | 0.92 |
| $\frac{1}{2}$ | 96% | 0.88 |

The total efficiency shall include losses of the auxiliaries such as independent excitation, motor-driven fans, lube-oil pumps etc. Over voltage surge protection shall be provided to protect motor.

8 STARTERS

Shall be automatic star delta starter or soft starter to ensure starting current at rated voltage & frequency does not exceed 2 times full load current. All components of starter shall be housed in dust proof enclosure and suitable for $415 \pm 10\%$ volts 50 cycles 3 phase AC power supply.

9 EVAPORATOR AND CONDENSER

- a. Shells and Water Boxes: Shells of evaporator and condenser shall be made from rolled carbon steel plate with fusion welded seams. Water boxes shall be of cast iron or welded steel with stub-out water connections provided to permit access for tube cleaning and replacement. Manufacturer's design for water boxes shall be suitable for 150 psig working pressure. These shall be factory hydraulically tested at 225 psig. The tubes finned from outside having spiral ridges from inside, roller expanded into the tube sheets providing a leak proof seal. They shall copper type shall have intermediate steel supports at intervals as recommended by the manufacturer.

- b. Chiller (Evaporator): Chiller shall be provided with eliminator to prevent liquid carry over to the compressor. It shall also be provided with liquid level sight glass and a relief device (of the bursting type) to prevent excess pressure in the vessel. The chiller shall be horizontal, shell and tube type, provided with the connections and accessories, but not limited to the following:

- i. Microprocessor panel having built in software / cards / program ready for connectivity to BAS.
- ii. Refrigerant inlet and outlet pressure gages.
- iii. Water inlet and outlet connections with Victaulic coupling
- iv. Factory fitted / provided flow switch at outlet.
- v. Drain and vent connections with stop valves.
- vi. Pressure gauges on water inlet and outlet connections.
- vii. De scaling valves.

Chiller shall be factory insulated minimum with 25 mm thick rubber based closed cell polyurethane foam or as recommended by manufacturer for tropical areas. The insulation shall be applied in such a manner that water boxes and covers shall be removable without damaging it.

- c. Water cooled Condenser: The condenser shall be of same construction as for chiller above but shall be without insulation. It shall be complete with the accessories as mentioned above and as defined in the schedule of quantities. Shell side volume of the condenser shall be suitable to contain complete refrigerant charge in case of pump-down. In case of chiller with de-superheated, main condenser shall be sized for 100% heat rejection duty.

10 ECONOMISER SUBCOOLER

Each chiller shall be provided with shell and tube / PHE / flash chamber type economizer. Condensed liquid in condenser shall be taped off and shall be expanded at intermediate pressure with expansion valve. Value of intermediate pressure (P_i) shall be as follows.

$$P_i = (P_c P_{er})^{0.5}$$

Where P_c = saturated condensing pressure (abs)

P_{er} = Saturated Evaporation Pressure (abs)

The liquid expanded to intermediate pressure shall be used to absorb enthalpy from remaining liquid refrigerant in order to provide sub-cooling. Vapor refrigerants due to above heat transfer shall again be admitted to compressor at intermediate pressure port.

11 INSTALLATION

Water chilling machine shall be installed on cement concrete platform as recommended by the manufacturer and shall be adequately isolated as per manufacturer's recommendations against transmission of vibrations to the building structure.

12 PAINTING

Water chilling machine shall be factory finished with durable enamel paint. Shop coats of paint that have become marred during shipment or erection, shall be cleaned off with mineral spirits, wire brushed and spot primed over the affected areas, then coated with enamel paint to match the finish over the adjoining shop-painted surfaces.

13 PERFORMANCE RATING

The unit shall be selected for the lowest operating noise level Capacity ratings, and power consumption with operating points clearly indicated along with the after. These parameters shall be verified at the time of testing and commissioning of the installation. Capacity shall be ascertained by measurements of chilled water flow rate and temperature at in and out of the chilling unit.

Power consumption shall be computed from measurements of incoming voltage & input current to the chilling machine. Sound Pressure level for Air cooled chillers shall not exceed 75dBA at 1m distance from chiller.

14 WITNESS TESTS

Water Chilling Machines at works, before shipment, shall be inspected to witness performance test by Consultant and Owner's representative to verify various performance parameters as confirmed by vendor earlier at the time of award of contract. Performance test shall be carried out as per procedure laid down by ARI / EUROVENT and as per specified parameters, at 100%, 75%, 50% & 25% loading. Temperature of leaving chilled water shall be kept constant during part load testing.

Fouling factor simulation for condenser and evaporator shall be done as per ARI-550/590-2003. Incremental temperature difference (to be calculated based on Normative appendix-C of ARI-550/590-2003) on account of designed fouling factors shall be added in condenser water entering temperature and shall be subtracted for leaving chilled water temperature. Chiller shall produce design refrigeration capacity and guaranteed power consumption at these corrected set of entering condenser water and leaving chilled water temperature. Outside tube surface area (for condenser and flooded evaporators) and inside tube surface area (for DX-Evaporator), being inputs for ARI mathematical model for fouling, shall be submitted along with the offer.

All expenses inclusive of business class airfare, boarding lodging etc. relating to the witness test will be borne by the vendor / contractor.

SECTION - II : PUMPS

1 SCOPE

The scope includes the supply, erection, testing and commissioning of water pumps conforming to these Specifications and in accordance with requirements of Schedule of Quantities.

2 CAPACITY

Water flow rate and head of the pump shall be as mentioned in the Schedule of Quantities.

3 TYPE

The type and size of all water, pumps for air conditioning applications shall be as per these specifications, approved for construction shop drawings and Schedule of Quantities.

4 SPLIT CASING PUMPS

- a. Pump casing shall be of heavy section cast iron, horizontally/vertically split, making possible complete servicing of rotating parts without disconnection piping or motor connections. Motor to pump connection shall be through flexible coupling type. Suction passages shall be in form of volute promoting smooth entry to impeller and increased efficiency. Impeller shall be bronze or gun metal, double suction, enclosed type, hydraulically balanced and smoothly-finished passages for minimum friction and maximum efficiency. Shaft shall be steel, protected by gunmetal sleeves extending through stuffing boxes. Stuffing boxes shall be extra deep, water sealed with renewable bushes. Shaft shall be supported in ball /journal bearings, grease lubricated, contained in easily removable housing. Pumps shall be factory fitted with mechanical seals, an air valve, two grease lubricators, drain plug and water seal drain connections.
- b. Motor shall be energy efficient, totally enclosed, fan-cooled, class-F insulation. Motor shall be specially designed for quiet operation and its speed shall be 1440 rpm. The motor rating shall be such as to ensure non overloading of the motor throughout its capacity range. Motor shall be suitable for $415 \pm 10\%$ volts, 3 phase, 50 cycles AC, power supply.
- c. Base shall be of a size suitable for the pump, motor and shaft and shall be constructed of cast iron or welded steel. Flexible coupling shall be protected by a guard mounted on the common base.
- d. Installation: The pump shall be installed on a concrete foundation with vibration isolators as per Approved-for-Construction shop drawings/Schedule of Quantities and as recommended by the manufacturer.

5 MONOBLOCK PUMPS

- a. Mono block Pump shall be end-suction design directly connected to motor with mechanical seal. The pump casing and impeller shall be of cast iron. It shall be hydraulically balanced and keyed to shaft. Stuffing boxes shall be part of casing and water be sealed. Shaft sleeve shall be of gun metal extending through stuffing boxes.
- b. Motor shall be SPDP (drip and splash proof) designed as integral part of pump. Pump motor shall be suitable for $415 \pm 6\%$ volts, 3 phases, 50 cycles AC power supply.
- c. Installation: The pump base shall be mounted on a concrete foundation block as per Approved-for-Construction shop drawings.

6 LUBRICATION

When system installation is complete, before testing, the pump shall be lubricated as per instruction manual of the manufacturer.

7 PUMP ALIGNMENT

In case of Split casing pumps, these shall be aligned at project site with a dial indicator within 0.05 mm., before starting / testing & commissioning.

8 PERFORMANCE DATA

Pump performance curves and power consumption with operating points clearly indicated shall be submitted at time of quote / before ordering and verified at the time of testing and commissioning of the installation.

9 PAINTING

The entire assembly pumps (with motor) shall be supplied with approved finish. Shop coat of paint that have damaged during shipment or erection shall be cleaned off with mineral spirits, wire brushed and spot primed over the affected areas, then coated with enamel paint to match the total assembly.

10 TESTING

All pumps shall be tested at factory as per relevant BIS codes. Routine and type test certificates shall be furnished for the pumps. Pump performance shall be computed from the pump curves provided by manufacturer during testing & commissioning at site.

SECTION - III : VARIABLE SPEED PUMPING SYSTEM

1 SCOPE OF WORK

This section includes the supply, erection, testing and commissioning of variable speed pumping package consisting of following:

- a. Pump Control Panel
- b. Adjustable Frequency Drive
- c. Differential pressure transmitters / switches.
- d. Logic Programming for sequence of Operation
- e. Power wiring and control wiring shall be carried out by installation contractor as included in schedule of quantities and as shown on the field connection drawings and wiring diagrams supplied with the pumping package by the manufacturer / his representative.

2 REFERENCES

- a. NEC - National Electrical Code
- b. UL - Underwriters Laboratories Inc.
- c. NEMA - National Electrical Manufacturers Association
- d. ANSI - American National Standards Institute
- e. ETL - Electrical Testing Laboratories
- f. CSA - Canadian Standards Association
- g. ISO - International Standards Organization
- h. IEC - International Electrochemical Commission

3 TECHNICAL SUBMITTALS

It shall include the following and shall be project specific & not general.

- a. Sequence of operation
- b. Shop drawing indicating dimensions, required clearances and location and size of each field connection.
- c. Power and control wiring diagrams.
- d. System profile analysis including variable speed pump curves and system curve. The submittal shall also include pump, motor and Adjustable Frequency Drive (AFD) efficiencies, job specific load profile, staging points, horse power and kilowatt/hour consumption.
- e. System summary sheet.
- f. Pump data sheets.

4 QUALITY ASSURANCE

- a. The pumping package shall be assembled in the presence of pump manufacturer / his representative. The "Unit Responsibility" for the complete pumping package shall be of the manufacturer / supplier. Unit responsibility shall be defined as responsibility for interface and successful operation of all system components supplied by the pumping system manufacturer/supplier.
- b. The local supplier of Chilled Water Variable Speed Pumping System (VSPS) shall have relevant expertise in all aspects of design, application engineering, installation, programming, interfacing, commissioning and after sales service. Supplier must have commissioned minimum 10 sets of chilled water VSPS in India.
- c. All functions of the variable speed pump control system shall be factory tested (prior to shipment) with motor connected to AFD output.
- d. The manufacturer shall be International Standards Organization (ISO) certified. Proof of this certification may be furnished at time of technical submittal.
- e. Manufacturer shall be listed by Underwriters Laboratories or EN as manufacturer of packaged pumping systems.
- f. Vendor / Contractor to comply with all sections of these specifications related to packaged pumping system. Any deviation, if any, from specifications shall be clearly defined in writing at time of bid. If no exceptions are taken at time of bid and duly approved by the Consultant, the supplier shall be bound by these specifications.

5 ASSEMBLED UNITS

- a. Supplier / Contractor to install a Variable Speed Pumping System as per approved shop drawings & manufacturer's instructions.
- b. The control system shall include minimum one programmable logic pump controller for each set of pumps along with adjustable frequency drive(for each pump) and remote sensor / transmitters as required to make these system complete. Additional items shall be included as specified or as required to properly execute the sequence of operation and to make the installation complete in all respect.
- c. The variable speed pump logic controller, adjustable frequency drives, AFD bypass (if indicated in schedule of quantities) and remote sensor / transmitters shall be shipped as individual components to the job site and installed by the HVAC contractor as shown on the plans.
- d. Power wiring shall be installed by the HVAC contractor as per approved field connection drawings and wiring diagrams supplied with the pumping package by the manufacturer / supplier.
- e. Low voltage control wiring shall be supplied & installed by the HVAC contractor as shown on the field connection drawings and wiring diagrams supplied with the pumping package by the manufacturer / supplier.

6 PUMP LOGIC CONTROLLER

- a. The pump logic controller assembly shall be Underwriter's Laboratory INC. (UL) listed. The controller shall be specifically designed for variable speed pumping applications.
- b. The controller shall function to safeguard against hydraulic conditions including :
 - i. Hunting
 - ii. Pump flow surges
 - ii. System over pressure.
 - iii. Motor overload
- c. The pump logic controller shall be capable of receiving up to two discrete analog inputs from zone sensor / transmitter as indicated on the plans. It will then select the analogue signal that has deviated the greatest amount from its set point. This selected signal shall be used as the command feedback input for a hydraulic stabilization function to minimize hunting. Each input signal shall be capable of maintaining a different set point value. Controller shall be capable of controlling up to three pumps in parallel.
- d. The pump logic controller shall have an additional analog input for a flow sensor. This input shall serve as the criteria for the end of curve protection algorithm.
- e. The hydraulic stabilization program shall utilize a proportional-integral-derivative control function. The proportional, integral and derivative values shall be user adjustable over an infinite range.
- f. The pump logic controller shall be self-prompting. All messages shall be displayed in plain English. The operator interface shall have the following features :
 - i. Multi-fault memory and recall last 10 faults and related operational data
 - ii. Red fault light, yellow warning light and Green power on light.
 - iii. Soft-touch membrane keypad switches.
- g. The display shall have four lines, with 20 characters on three lines and eight large characters on one line. Actual pump information shall be displayed indicating pump status.
- h. Controller shall be capable performing the following pressure booster function:
 - i. Low suction pressure cut-out to protect the pumps against operating with insufficient suction pressure.
 - ii. High system pressure cut-out to protect the piping system against high pressure conditions.
 - iii. No flow shut down to turn the pumps off automatically when system demand is low enough to be supplied by hydro pneumatic tank. No flow shutdown shall require any external flow meters, flow switches, nor does pressure switch to determine when a No Flow condition exists.
- i. This system shall be compatible for following through BAS:
 - i. Remote system start / stop.
 - ii. Failure of any system component with alarm indicator.
 - iii. Selectable output of 4-20 am for
 - Output Power
 - Output Current
 - Frequency
 - Process Variable

- j. This system shall be equipped with RS-485 port utilizing open protocol & shall have following features communicable through BAS for each equipment:
 - i. Analog Input
 - ii. Zone Set Points.
 - iii. Pump / AFD on/off status.
 - iv. 1 KW signals.
 - v. Percentage speed.
 - vi. System Operation mode.
 - vii. System Start / Stop command
 - viii. System flow, for through flow sensor.
- k. The pump logic controller shall be of approved make & directly provided by the manufacturer. It shall be housed in a NEMA 1 Enclosure & not in plastic enclosure.

7 **ADJUSTABLE FREQUENCY DRIVE**

- a. The Adjustable Frequency Drive (AFD), shall be factory tested as per UL standard 508. The AFD shall also be CE marked and built to meet ISO 9001 standards.
- b. The adjustable frequency drives shall be microprocessor controlled design with Pulse Width Modulation (PWM).
- c. The AFD shall have voltage vector control to minimize harmonics to the motor to increase motor efficiency and lift. It shall be capable to maintaining power factor near to unity regardless of speed or load.
- D Input and output power circuit switching can be done without interlocks or damage to the AFD.
- e. The AFD shall have balanced DC link reactors to minimize power line harmonics AFDs without a DC link reactor shall provide a 3% impedance line reactor.
- f. The following adjustments shall also be part of the system.
 - i. Acela time.
 - ii. Decal time.
 - iii. Minimum Frequency.
 - iv. Maximum Frequency.
- g. This system shall have in-built automatic energy optimization selection feature. This feature shall reduce voltage when lightly loaded and provide a 3% to 10% additional energy savings.
- h. The AFD shall be suitable for operating ambient temperature of not less than 104 degrees F and also able to operate at 1000 Mt. elevation above sea level without de-rating. AFD shall be suitable for operation in environments up to 955 non-condensing humidity.
- k. The AFD shall have the following display information in English :
 - i. Voltage
 - ii. Current
 - iii. Frequency.
 - iv. RPM
 - v. Kilowatts per hour
 - vi. Fault Identification.
 - vii. Percent Torque.
 - viii. Percent Power

8 AUTOMATIC AFD BYPASS

- a. AFD at variable speed pumping system shall be equipped with an automatic bypass with requirement of Schedule of Quantities.
- b. Bypass shall consist of a main power disconnect with earth fault protection, suitable starter with motor overload relay. All are to be mounted in a NEMA 1 enclosure.
- c. Automatic bypass shall operate as described in the sequence of operation.

9 SENSOR / TRANSMITTERS

- a. Field mounted differential pressure sensor transmitters shall be provided as indicated in BOQ or as identified in the plans. Unit shall transmit an isolated 4-20mA DC signal indicative of process variable to the pump logic controller via standard two wire 24 DC system. Unit shall have a corrosion resistant steel body with 1/8" NPT process connection. It shall have a NEMA 1 electrical enclosure capable of withstanding 450 PSI static pressure. Accuracy shall be within 0.5% of full span. The installation contractor shall provide pilfer proof housing such MS plate housing with lockable access panel for differential pressure sensors.

10. PUMP ASSEMBLY

- a. For, Flow rate up to 1800 GPM (Per Pump in the system)

"True Back Pull Out Design" End suction vertical split flexible coupled with tangential flow design volute for better efficiency, coupled with motor, spacer coupling, OSHA complaint coupling guard, in CI Casing Construction & SS Cast grade (CF8)/Bronze fitted Impeller construction, specifically designed for quiet operation for chilled water cooling systems as indicated on the drawings.

 - The pumps shall be Suitable for standard operations at 225 F and 125 PSIG working pressure or optional operations at up to 250 F and 250 PSIG working pressures. Working pressures shall not be de-rated at temperatures up to 250F. The pump internals shall be capable of being serviced without disturbing piping connections, electrical motor connections or pump to motor alignment.
 - The bearing assembly shall be of High Strength Steel shaft. A non-ferrous shaft sleeve shall be employed to completely cover the wetted area under the seal.
 - Pump volute shall be of a cast iron design for heating systems (or cast bronze for domestic water systems) with integrally cast pedestal volute support, rated for 175 PSIG with integral cast iron flanges drilled for 125# ANSI companion flanges. (Optional 250 PSIG working pressures are available and are 250# flange drilled) Volute shall include gauge ports at nozzles, and vent and drain ports.
 - Pumps with overhung volute shall not be acceptable
 - Shut off Head should be more than 10% of duty point head.
 - Pump Curve should be continuously rising from High flow to zero Flow, drooping curves are not acceptable.
 - Specially Designed Motors: shall meet High Efficiency) & scheduled horsepower, speed, voltage, and enclosure design. Pump and motors shall be factory aligned, and shall be realigned after installation by the manufacturer's representative.
 - End suction pump has to be "Back Pull-Out" Truly defined; the statement should indicate ease of service and disassembly of the pump for service. Specifically, the bearing frame and impeller should be able to be removed for service without disturbing the pump volute or motor assembly. This capability substantially reduces pump downtime and decreases maintenance costs.

- **CONDITION MONITORING SYSTEM:** Continuously measures vibration and temperature at the outboard bearing and automatically indicates when pre-set levels of vibration and temperature have been exceeded, so that changes can be made before failure occurs. A visual indication of pump health makes walk around inspections more efficient and accurate. This onboard pump intelligence helps minimize life-cycle costs while maximizing performance.
- **Specially Designed Coupling guard:** complies with ANSI B15.1 and OSHA 1910.219. The guard offers increased Protection against potential injuries. The guard includes slotted viewing windows for easy inspections. "U" Shape Coupling Guard shall not be acceptable.

11. OPERATION SEQUANCE

Sequence of Operation, for Primary Variable Speed Pumping System:

1. The system shall consist of a Technologic pump logic controller, multiple pump/VFD sets with manual and automatic alternation and pump staging.
2. The pumping system shall start upon the closure of customer's contact when the pump logic controller Mode of Operation selector switch is in the REMOTE position.
3. When the pump logic controller selector switch is in the LOCAL position, the pumping system shall operate automatically.
4. Sensor/transmitters shall be provided as indicated on the plans.
5. Each sensor/transmitter shall send a 4-20mA signal to the pump logic controller, indicative of process variable condition.
6. The pump logic controller shall compare each signal to the independent, engineer/user determined set points.
7. When all set points are satisfied by the process variable, the pump speed shall remain constant at the optimum energy consumption level.
8. The pump logic controller shall continuously scan and compare each process variable to its individual set point and control to the least satisfied zone:
 - The First priority: The Technologic controller shall monitor the zone differential pressure sensors and compare actual process values with the required set points. The pump speed is modulated to maintain set point. Pump staging will occur if required to meet set point.
 - The Second priority of the Technologic control system will be to ensure that minimum flow requirements are being met for all running chillers.
 - Technologic will monitor individual chiller flows or DP signals, along with digital input signals from each chiller.
 - If the speed signal or the actual flow or DP is not high enough the bypass valve will be opened to the user defined initial opening value and modulate as needed to ensure minimum flow. Display shall indicate valve position.
 - Upon sufficient increase in system flow, valve will modulate to the closed position.

- The Technologic controller will provide each pump an off delay when a chiller is de-staged or turned off to prevent freezing. When the chiller start and chiller running digital input signals (from the chiller to the Technologic) are turned off the chiller isolation valve will close and the pump will continue to operate.
 - The display will indicate that the isolation valve is now closed. The pump will continue running until the process variable or end of curve de-staging logic determines it is time to turn off the pump.
 - The Third priority of the Technologic control system is to monitor system flow rate to prevent operation above the maximum flow for the chillers and the pumps.
 - When the system flow exceeds the maximum flow rate that the operating chillers can handle the Technologic controller will send out a DO signal to request that the next chiller in sequence be turned on.
 - The display will indicate that the maximum flow has been exceeded.
 - End of curve staging shall be active.
 - To eliminate rate of change issues, the PID output buffer may be enabled through user-setup for use during manual to automatic transitions.
9. If the set point cannot be satisfied by the designated lead pump, the pump logic controller shall initiate a timed sequence of operation to stage a lag pump.
 10. The lag pump shall accelerate resulting in the lead pump(s) decelerating until they equalize in speed.
 11. Further change in process variable shall cause the pumps to change speed together.
 12. When the set point criteria can be safely satisfied with fewer pumps, the Technologic pump logic controller shall initiate a timed restage sequence and continue variable speed operation.
 13. As the worst case zone deviates from set point, the pump logic controller shall send the appropriate analog signal to the VFD to speed up or slow down the pump/motor.
 14. In the event of a system differential pressure failure due to a pump or VFD fault, the Technologic pump logic controller shall automatically start the next variable speed pump/VFD set in sequence and continue variable speed operation.
 15. In the event of the failure of a zone sensor/transmitter, its process variable signal shall be removed from the scan/compare program. Alternative zone sensor/transmitters, if available, shall remain in the scan/compare program for control.
 16. The zone number corresponding to the failed sensor/transmitter shall be displayed on the operator interface of the pump logic controller.
 17. In the event of failure to receive all zone process variable signals, all VFDs shall maintain 100% speed; reset shall be automatic upon correction of the zone failure.
 18. PUMP or VFD fault shall be continuously scrolled through the display on the operator interface of pump logic controller until the fault has been corrected and the controller has been manually reset.

12. PROJECT EXECUTION

a. INSTALLATION

- i. Install equipment in accordance with manufacturer's instructions.
- ii. The contractor shall align the pump and a motor shaft to within the manufacturer's recommended tolerances prior to system start-up in the presence of manufacturer's authorized representative.
- iii. Power wiring, as required, shall be the responsibility of the electrical contractor. All wiring shall be performed per manufacturer's instructions and applicable state, federal and local codes.
- iv. Control wiring for remote mounted switches and sensor / transmitters shall be the responsibility of the contractor. All wiring shall be performed per manufacturer's instructions and applicable state, federal and local codes.

b. DEMONSTRATION

- i. The system manufacturer or trained representative shall provide start-up of the packaged pumping system. This start-up shall include verification of proper installation, system initiation, adjustment and fine tuning. Start-up shall not be considered complete until the sequence of operation, including all alarms, has been sufficiently demonstrated to the owner or owner's designated representative. This jobsite visit shall occur only after all hook-ups, tie-ins, and terminations have been completed and signed-off on the manufacturer's start-up request form.
- ii. The system manufacturer or trained representative shall provide on-site training for owner's personnel. This training shall fully cover maintenance and operation of all system components.

SECTION : IV - AIR HANDLING UNITS

1 SCOPE

It includes the supply, erection, testing and commissioning of double skin type air handling units, conforming to these Specifications and as detailed in the Schedule of Quantities and approved shop drawings.

2 TYPE

The air handling units shall be double skin construction, horizontal or vertical type through blow through type comprising of various sections i.e. filter section/s coil section/s and fan section. Mixing box (with dampers), (wherever the return air, or and fresh air are ducted) as included in schedule of quantities and shown in shop drawings.

3 CAPACITY

The air handling capacities in terms of air delivery, maximum motor horse power and static pressure shall be as identified in Schedule of Quantities and in shop drawings.

4 CASING

Double skinned panels of AHUs shall be 46mm thick for recirculation type AHUs & 46mm thick for TFA AHUs & outdoor type AHUs. These shall be made of galvanized steel, pressure injected with foam insulation (density 40 kg/m³) these panels shall be fixed to minimum 1.5 mm thick aluminum alloy structural framework with stainless steel screws. Outer sheet of double skinned panels shall be made of pre-plasticized galvanized sheet, and inner sheet of plain G.I. Sheet, both inner & out shafts shall be of 24 gauge.

The entire framework shall be mounted on an aluminum alloy or galvanized steel channel base as per manufacturer's design. Sealing of panels to the frame work shall be through heavy duty 'O' ring gaskets held captive in the framed extrusion. All panels shall be detachable or hinged. Handles for panels shall be made of hard nylon and shall be operational from both inside and outside of the unit. Units supplied with various sections shall be suitable for onsite assembly gaskets shall be continuous & concealed. AHU shall have hinged, access door in the fan section and also in filter section where filters are not accessible from outside. Access doors shall be part of double skinned panels. AHU shall have 18 gauge stainless steel sheet condensate drain pan. It shall be isolated from bottom floor panel through insulation as per manufacturer's standards.

5 MIXING BOX

Mixing box shall be provided to AHUs specified in Schedule of Quantities and shall be along with fresh air and return air dampers.

6 THERMAL BREAK PROFILE

TFA AHUs & AHUs with mixing box having ducted return air, shall be provided with thermal break profile whatever or not indicated in schedule of quantities.

7 DAMPERS

Dampers provided at supply air inlet, return air & fresh air intake shall be opposed blade type made of double skinned aero foil aluminum sections, assembled within a rigid extruded aluminum alloy frame work with gasket. All linkages shall be made of aluminum or nylon, having Teflon bushes. Dampers shall be provided with a Bakelite knob for locking the damper blades in position.

Linkages shall be extended wherever specified for motorized operation. Damper frames shall be manufacturer in such a way that blades never wrap. Air leakage in the closed position of dampers shall not exceed 1.5% of the total flow rate at the maximum design air total pressure.

8 MOTOR AND DRIVE

AHU fan motors shall be energy (TEFC) efficient *suitable for* 415±10% volts, 50 cycles, three phase, supply motor shall be totally enclosed fan-cooled class F, with IP-55 protection. Motors shall be designed for quiet operation and motor speed shall not exceed 1440 rpm. Drive forwarded to fan shall be provided through pulley belt-drive arrangement. Belts shall be oil-resistant type.

9 FAN

AHU fans as per schedule of quantities either are forward inclined blades (suitable for static pressure up to 70 mm Wig) or backward inclined blades (for static pressure above 70 mm Wig). AHU fan motor driven by variable frequency drive shall have backward inclined irrespective of static pressure casing of fan shall be made of galvanized steel sheet. Fans shall be selected for minimum efficiency of 75%. Fan wheels shall be made of galvanized steel. Fan shaft shall be of carbon steel, supported in self-aligning Plummer block, grease lubricated bearings. Fan wheels be tested and balanced dynamically. Fan motor assembly shall be statically and dynamically balanced as per relevant ISO/AMCA standard. Computerized fan selection print outs shall be submitted along with the offer/ technical submittal.

Motors shall be totally enclosed, fan cooled, to be class ' F' insulation. It shall be mounted inside the AHU casing on slide rails for easy belt tensioning. Motors drive shall be heavy duty V-belt, having constant pitch, suitably selected for rated motor horsepower.

Both fan and motors assemblies shall be mounted on aluminum alloy or galvanized steel base frame, as per the manufacturer's standard.

Anti-vibration manuals consisting of spring & rubber combinations shall be provided for isolating the unit casing against vibration transmission. Flame retardant, waterproof silicone rubber impregnated flexible connection shall be provided at the fan discharge.

10 CHILLED WATER COIL

Cooling coil shall be minimum 0.4mm thick & shall have 12.5 to 15 media (O.D)tubes with sine wave aluminum fins firmly bonded to copper tubes. These shall be assembled in zinc coated steel frame.

Surface areas shall to ensure rated capacity of each unit and such that the air velocity across the coil shall not exceed 150 meters per minute. The coil shall have copper headers with supply & return water connections. These shall protrude out of AHU casing by minimum 150 mm and fitted with dielectric coupling for connection with MS pipes. Each coil shall be factory-tested at 21 kg per sq. m air pressure under water.

Tube shall be mechanically / hydraulically expanded for minimum thermal contact resistance with fins. Fins shall have spacing of 4 - 5 fins per cm. Water pressure drop in coil shall not exceed 10 Signal recirculation type of AHU's shall be provided with minimum 6 Row Cooling Coil. All treated fresh air (TFA) AHU's shall be provided with minimum 8 row cooling coil. Hot water reheat coil shall be minimum 2 rows deep. Coil rating shall be as per ARI-410/2006. Computerized cooling coil selection output shall be part of technical submittal.

11 FILTERS

Each AHU shall be supplied with a factory assembled filter section. This shall be provided with washable synthetic type air filters having anodized aluminum frame. The filters shall have minimum 90% efficiency down to 10 microns. The media shall be supported with HDP mesh on one side and aluminum mesh on other side. Filter banks shall be easily accessible and designed for easy withdrawal and renewal of filter cells. Filter framework shall be and constructed from aluminum alloy and should be fully sealed.

Certified for Green Building each AHU shall also be provided with filter section containing MERV-13 type air filters having anodized aluminum frame. The filter shall have minimum 99% efficiency down to 3 microns.

12 ACCESSORIES

Coil of each air handling unit shall be provided with manual air vent at high point and drain plug in the bottom. In addition, the following accessories shall be required at air handling unit, their detailed specifications are given in individual sections, & quantities separately identified in schedule of Quantities.

- a. Insulated butterfly valves, balancing valves, 'Y' strainer, union & condensate drain piping with 'U' trap up to sump or floor drain in air handling unit room, (or up to sump) as described in section "Piping" (part of piping).
- b. Thermometers in the thermometer wells & pressure gauge (with cocks) within gauge ports in chilled water supply and return lines as per the section "Instruments".

13 ISOLATORS

Vibration isolators shall be provided with all air handling units as per manufacturer's recommendation. Vibration isolators shall be cushy foot mounting type. Else these shall be of enplane pads 2 Nos. each having minimum thickness of 25mm sandwiched in GI sheet. Minimum vibration isolation efficiency shall be 90%.

14 FRESH AIR INTAKES

Anodized extruded aluminum construction fresh air louvers with bird screen pre filters and dampers shall be provided in the external masonry walls of the air handling unit rooms. Fresh air dampers shall be of the interlocking, opposed-blade louver type. Blades shall be made of extruded aluminum construction and shall be rattle-free. Dampers shall be similar to those specified in "Air Distribution". Fresh air fans and fresh air intakes shall be as per the requirements of Schedule of Quantities.

15 PERFORMANCE DATA

AHU selection shall be for the lowest operating noise level. Fan performance curve and power consumption data, with operating point indicated shall be submitted in technical submittals which shall be verified at the time of testing and commissioning of the installation.

16 PAINTING

Shop coats of paint that have become marred during shipment or erection shall be cleaned off with mineral spirits, wire brushed and spot primed over the affected areas, then coated with paint to match the finish over the adjoining shop painted surface.

17 TESTING

Cooling / heating capacity of each air handling unit shall be computed from the measurements of air flow and dry and wet bulb temperatures of air entering and leaving the coil. Flow measurements shall be by voltmeter anemometer and temperature measurements by accurately calibrated mercury-in-glass thermometer. Computed results shall conform to the specified capacities and quoted ratings. Power consumption shall be measured from watt. Incoming voltage and input current.

SECTION - V : FAN COIL UNITS

1 SCOPE

The scope shall include the supply (may be directly by the manufacturer) installation, testing and commissioning of fan coil units. The FCU shall conforming to these Specifications and shall meet the requirements of the Drawings and Schedule of Quantities.

2 TYPE

The fan coil units shall be horizontal type for ceiling-suspension and vertical type for floor mounting. Horizontal units mounted within ceiling space shall have horizontal discharge and shall be duct able. Floor-mounted vertical units shall have vertical top discharge. All units shall be complete with chilled / hot water coil, centrifugal fan and motor both on common shaft, cleanable fabric filters, double-skinned insulated condensate drain pan.

3 CAPACITY

The air delivery and cooling/heating capacities shall be as identified on Drawings and indicated in Schedule of Quantities.

4 CABINETS

FCU designed shall be constructed of 20 gauge die-formed cold-rolled galvanized sheet steel, and powder coated with approved shade / color. Horizontal furred-in type units mounted within ceiling space shall be provided with a cabinet housing containing the coil and fan section with provision to mount filters within the fan section either of the back or at the bottom. For vertical FCU the cabinets shall be of sufficient size to house all piping and control valves and shall have access doors to piping and controls. Access panels shall have positive locking fasteners for easy removal.

5 INTERIOR CHASSIS

The interior chassis of FCU shall be constructed of minimum 18 gauge cold rolled galvanized sheet steel painted with approved shade of powder coating finish. All vertical fan coil units shall be securely mounted on the building structure. Filter, fan, motor & coil shall be easily accessible / removable in. In case of ceiling suspended horizontal units fan deck and cooling coil shall be easily removable from FCU without lowering down of the entire FCU without disturbing the other installation.

6 DRAIN PAN

Primary drain pan shall be fabricated from 20 gauge cold rolled galvanized sheet steel with all corners welded, and an additional inner bottom panel of 20 gauge cold rolled galvanized sheet steel shall be provided to prevent damage to, and floatation of the bottom panel insulation. The pan shall be insulated with not less than 15 mm thick expanded polystyrene or 8 mm thick expanded polyethylene insulation sandwiched between top and bottom panels to effectively prevent condensation.

The pan shall of sufficient size to catch all drip page of condensation from any part of the unit. The primary pan shall have extended tray large enough to cover supply and return water valve assembly and control valves.

A secondary (auxiliary) condensate pan similar to primary drain pan may be provided by the manufacturer to these units which are so identified in Schedule of Quantities. All drain pans shall be with powder coating finish as per interior chassis defined above.

7 COOLING COIL

Cooling coils shall be standard three-row of copper tube with aluminum sine wave fins having spacing of 10 to 12 fins per inch. The inlet / outlet connections of coil shall be fitted with dielectric coupling for connection with MS pipes. Tubes shall be minimum 10 mm OD and wall thickness shall be minimum 0.5 mm. Tubes shall be mechanically / hydraulically expanded for minimum thermal contact resistance with fins. Air vent shall be provided at top of the headers of coils. The coil shall be easily removable from back side of FCU without removing the FCU cabinet. Coils shall be factory tested at 21 KG per sq. cm (300 psig) air pressure while submerged in water.

8 FANS

Fans shall be centrifugal forward curve double inlet duct able direct driven.

9 MOTOR

Motor shall be energy efficient, six pole, shaded pole type, suitable for 220+ 6% volts, 50 cycle's single phase power supply. Speed shall not exceed 1000 rpm at maximum airflow. Motors shall have three speed windings and shall be factory wired to a terminal block mounted within the fan section. Motors shall have extended shaft on both sides.

10 INSTALLATION

Ceiling suspended horizontal units and units mounted within the ceiling space shall be hung through rubber-in-shear vibration isolator.

11 ACCESSORIES

All fan coil units shall be equipped with copper piping connections, dielectric union and manual air vent at the cooling coil outlet header. In addition, the following accessories may be required at fan coil units; their detailed Specifications are given in individual sections and quantities separately identified in Schedule of Quantities.

- a. Imported fan coil units as specified in Schedule of Quantities shall be factory fitted with Ball valves with Y-strainer at inlet and ball valve at outlet along with two way valve as shown in Drawings and included in Schedule of Quantities.
- b. Fire retardant double sleeve flexible canvas connection.
- c. Rubber in-shear type vibration isolators with hangers.

12 PAINTING

Shop coats of paints that have become marred during shipment or erection shall be cleaned off with mineral spirits, wire brushed and spot primed over the affected areas, then coated with enamel paint to match the finish over the adjoining shop painted surfaces.

13 PERFORMANCE DATA

Fan coil., units shall be selected for the lowest operating noise level having standard sound level rating of NC 30 at medium/high speed at a distance of 3 meters. Fan performance rating and power consumption data, with operating points clearly indicated, shall be submitted by the Contractor and verified at the time of testing and commissioning of the installation.

14 TESTING

Cooling capacity of various fan coil unit models shall be computed from dry and wet bulb temperatures of air entering and leaving the coil measured by accurately calibrated thermometer. Flow measurements shall be measured by anemometer. Power consumption shall be computed from measurements of incoming voltage and input current. Computed ratings shall conform to the specified capacities and quoted ratings.

SECTION : VI COOLING TOWERS

1 SCOPE

The scope of this section includes the supply, installation, testing and commissioning of cooling towers in as included in the Schedule of Quantities & as detailed in the approved from construction shop drawings.

2 TYPE

Cooling Towers shall be induced draft /forced draft as per the requirement of Schedule of Quantities.

3 INDUCED DRAFT COOLING TOWER

Cooling Tower shall be suitable for outdoor use. It shall be vertical, induced draft, counter/cross flow type. Tower shall be FRP / GI construction, in rectangular / round / square /octagonal profile, complete with fan, motor, diffusion deck, spray section, eliminators, steel supports and GI ladder etc. Sound attenuation equipment where called for shall be provided as per manufacturers standards or as included in Schedule of Quantities.

a. Capacity

The cooling tower capacities shall be as per Schedule of Quantities & approved for construction shop drawings.

b. Casing

This shall be made out of FRP construction of minimum 3 mm thick and UV stabilized with smooth surface on both sides for minimum resistance to air flow. Casing can be of GI also, as recommended by the manufacturer. Tower shall be sufficiently supported with structural members to withstand high wind velocities and vibration without any damage to the Cooling tower / Building structure. . The casing may be installed in the reinforced cement concrete basin if so identified in drawings, or in Schedule of Quantities. The tower supporting structure shall be made of hot dipped galvanized frame. Air intake shall be all along the sides (or as required by the manufacturer for tailor made cooling tower as per site conditions) so that tower can be installed quite independent of prevailing wind direction. Anodized aluminum or PVC louvers with UV stabilized PVC fill and backed up by galvanized bird screen / FRP louvers shall be provided at air intake. Sufficient clearance between casing / intake louvers and adjoining structures shall be provided to enable easy service and periodic cleaning.

c. Basin

Cold water basin shall be a deep slump and made minimum of 5 mm thick FRP construction, UV stabilized, on which cooling tower super structure shall be supported. RCC suction tank if made, shall be provided with easily removable double brass strainers with this basin. It will be separately identified in the shop drawings or in Schedule of Quantities and shall be cast by civil agency under the direct supervision of HVAC contractor as per approved shop drawings. Basin fittings shall include the following :

- i. Make up & quick fill connection to the side of basin.
- ii. Bottom / side outlet.
- iii. Connection from suction assembly with strainer.
- iv. Drain connection to the side / underside of basin.
- v. Overflow connection to the side / bottom of basin.
- vi. Built-in bleed off attached to inlet header discharging through polyethylene tube into overflow pipe.
- vii. Make up water connection with inlet valve & heavy duty float valve.
- viii. Equalizing connection for the battery of cooling towers.

d. Distribution System

Condenser / heat exchanger water distribution system shall comprise of header and branch arms system with gravity flow system.

e. Fill

Fillings shall be made of rigid PVC film in honey comb structure arranged in shape of cooling tower casing. Fill sheets shall be suspended from H.D.G steel structure supported from the main frame work facilitating cleaning and easy replacement of fills. These shall be arranged in to ensure negligible resistance to air flow and to eliminate back water spots. PVC drift eliminator shall be installed to reduce carry-over losses through entrainment of moisture drops in air stream.

f. Mechanical Equipment

Cooling tower shall be provided with low speed fan running through gears reducer at less than 360 RPM. Direct driven fan speed shall not exceed 700 RPM. Fan shall be of the propeller type with light-weight rotor fitted with multiple aero foil blades. Fan assembly shall be statically and dynamically balanced. Fan motor shall be energy efficient, totally-enclosed, fan-cooled, weather-proof construction, designed and selected to operate in humid air stream suitable for 415+ 10V, 3 phase, 50 Hz, AC supply. Fan shall be protected by a fan guard and bird screen of galvanized steel construction. A service ladder of GI / Aluminum construction shall also be provided for each cooling tower. The mechanical equipment assembly shall be adequately supported on a rugged steel base frame work assuring vibration-free assembly. G.I canopy shall be provided over the fan motor for weather protection. Motor terminal box shall also be made water tight.

The noise level from cooling tower shall not exceed 65 dB at a distance of 5 meters all around the cooling tower.

4 FORCED DRAFT COOLING TOWER

Forced draft cooling tower shall be FRP construction of minimum 3 mm thick and UV stabilized and structural framed, cross-flow type, suitable for outdoor use. Tower may also be of galvanized steel construction as per manufacturer's standards. . Tower shall be complete with fan, motor, diffusion deck, spray section and eliminator plate. Tower shall be selected for low height application and lowest possible noise level.

a. Capacity

The cooling tower capacity shall be as per Schedule of Quantities and shop buildings.

b. Casing

Casing and basin shall be of FRP of minimum 3 mm thick respectively and sealed for water tightness. All joints and corners shall be sealed and an aluminum / GI ladder shall be provided as a part of cooling tower.

c. Cold Water Basin

Cold water basin shall be a with deep slump with cooling tower superstructure/supports. Easily maintainable brass-strainer shall be provided with the basin.

Basin fittings shall include the following :

- i. Make up & quick fill connection to the side of basin.
- ii. Bottom / side outlet.
- iii. Connection from suction assembly with strainer.
- iv. Drain connection to the side / underside of basin.
- v. Overflow connection to the side / bottom of basin.

- vi. Built-in bleed off attached to inlet header discharging through polyethylene tube into overflow pipe.
- vii. Make up water connection with inlet valve & heavy duty float valve.
- viii. Equalizing connection for the battery of cooling towers.

d. Distribution System

Condenser / heat exchanger water distribution system shall comprise of header and branch arms system with gravity flow system.

e. Fill

Fillings shall be made of rigid PVC film in honey comb structure arranged in shape of cooling tower casing. Fill sheets shall be suspended from H.D.G steel structure supported from the main frame work facilitating cleaning and easy replacement of fills. These shall be arranged in to ensure negligible resistance to air flow and to eliminate back water spots. PVC drift eliminator shall be installed to reduce carry-over losses through entrainment of moisture drops in air stream.

f. Mechanical Equipment

Fan shall be centrifugal/axial fan, aluminum alloy aero foil construction. The entire fan assembly shall be statically and dynamically balanced. Fan motor shall be **low** RPM, suitable for 415±10% volts, 3 phase, 50 cycles AC supply, energy efficient electric motor, totally enclosed, fan-cooled, weather-proof construction. The noise level from cooling tower shall not exceed 65 dB from 5 meter distance all around the cooling tower. The mechanical equipment assembly shall be adequately supported through galvanized steel angle frame work. The hot and humid air shall be discharged at the top level. Galvanized steel construction bird screen at outlet shall be provided.

5 PERFORMANCE DATA

Technical submittal shall include complete performance ratings and power consumption at varying loads and at outdoor wet bulb temperatures. These shall be verified at the time of testing and commissioning of the installation.

6 TESTING

Cooling tower capacity shall be calculated from the measurements taken water flow, incoming/outgoing water temperatures and ambient air wet bulb temperature. Computed ratings shall conform to the specified capacities and quoted ratings. Power consumption for cooling towers shall be computed from measurements of incoming voltage and input current.

SECTION VII : AIR WASHERS & SCRUBBER

SECTION VII (A): AIR WASHERS

1 SCOPE

The scope of this section includes the supply, installation, testing and commissioning of (ECU) conforming to these specifications and in accordance with the schedule of quantities & shop drawings.

2 TYPE

The evaporative cooling unit shall be CELDEK fill type or spray type as identified in Schedule of Quantities.

3 CAPACITY

The air delivery of unit shall be as shown on drawings and Schedule of Quantities.

4 SPRAY TYPE EVAPORATIVE COOLING UNIT

The unit shall be with spray nozzles, draw through type with minimum 90% saturation efficiency.

Casing

It shall be of Double skinned panels having 23 mm thickness, made of galvanized steel. Double skin panels shall be pressure injected with foam insulation (density 40 kg/m³) with K factor not exceeding 0.02 watt / M deg C. These panels shall be fixed to 2.5 mm thick aluminum alloy box section structural framework with stainless steel screws. Outer and inner sheet of panels shall be galvanized iron having minimum thickness of 0.6MM. Inner sheet shall be plain G.I & outer sheet shall be pre-plasticized.

The panels shall be sealed to the framework by heavy duty 'O' ring gaskets held captive in the framed extrusion. The entire framework shall be mounted on an aluminum alloy channel base. All panels shall be detachable or hinged. Hinges shall be made of die cast aluminum with stainless steel pivots, handles shall be made of hard nylon and be operational from both inside and outside of the unit. Units may be supplied in knock down condition with various sections suitable for onsite assembly with continuous concealed foam gasket.

Units shall have access door in the fan and filter section. Access doors shall also be double skin type.

Water recirculation tank shall be fabricated from 18 gage stainless steel sheet with all corners welded. The tank shall have FRP lining.

Distribution Plate

Distribution plate shall be made of 24 gauge galvanized sheet steel supported with hot dipped galvanized angle iron frame having minimum 50% free area on intake side of evaporative cooling unit.

Spray Arrangement

Spray arrangement shall have 2 banks of air washer with 1/8" (3 mm) bore bronze nozzles with brass plug complete with GI pipes and spray headers. Minimum number of nozzles shall be 1 / sq ft of face area. Face velocity not to exceed 500 FPM (2.5 m/s).

Eliminator

Eliminator plates shall be bend made from 24 gauge galvanized sheet steel or PVC.

5 INTERCONNECTING PIPES

Evaporative cooling unit shall be complete with interconnecting GI piping from pumps to unit, valves, gauges, fittings, strainers etc. Unit shall be supplied complete with above accessories by the manufacturer /vendor.

6 PAINTING

Shop coats of paint that have become marred during shipment or erection shall be cleaned off with mineral spirits, wire brushed and spot primed over the affected areas, than coated with paint to match the finish over the adjoining shop painted surface.

7 TESTING

Efficiency of evaporative cooling unit shall be computed from the measurements of air flow and dry and wet bulb temperature of air entering and leaving the air washer and ambient temperatures.

SECTION VII (B): SCRUBBER

1 SCOPE

The scope of this section comprises the supply, erection, testing and commissioning of dry scrubbers comprising of electrostatic sections for use in kitchen exhaust / grease / exhaust air treatment.

2 TYPE

The unit shall be CE certified and of the type as indicated on Drawings and identified in Schedule of Quantities.

3 CAPACITY

The air-moving capacity of unit shall be as shown on Drawings and in Schedule of Quantities.

4 TECHNICAL PARAMETERS

The unit shall provide efficiency of 90% or better for single pass base on ASHRAE test method at flow rates of 800 –1500CFM per module. Multiple units can be joined together for increased volume. The system shall be suitable to connect to fan section with average velocity of 500 FPM across air cleaner.

5 EQUIPMENT SPECIFICATIONS

The unit shall be designed and constructed and supplied by a manufacturer specializing in the research, design and manufacture of products specified in this section with a minimum of three years of documented experience, and capable of issuing complete catalog data on the total product.

6 UNIT HOUSING

Housing shall be minimum 1.2 mm thick zinc coated steel construction to protect against rust and corrosion. Each section shall include single door access, located one side of the unit.

The access door shall be mounted on steel hinges and secured with adjustable, gasket sealed lever latches allowing for component access and removal. All doors shall be casketed to prevent air and water leakage. Doors to charged high voltage components shall be equipped with electrical interlocks, for interconnection into the primary power supply, to prevent access when the components are energized. The housing shall be furnished completely assembled for ease of shipment and installation. Between each section, a permanent 1/8" thick gasket shall be installed to prevent leakage. The bottom drain pan under ESP section containing integral washing systems shall be pitched downward 1/4" per foot minimum toward a 3" NPT drain nipple.

7 BASE CONSTRUCTION

The sections are to be mounted on a structural C-channel or floor mounting or ceiling suspension. Lifting lugs shall be incorporated in the base channel to allow for rigging, if ordered.

8 FINISH

The external casing finish shall be a durable industrial grade semi-gloss baked-on epoxy ester, not less than 3 mil minimum thickness.

9 ELECTROSTATIC PRECIPITATOR MODULE

The electronic air cleaner shall be the two-stage dual voltage plate type cells, rated at not less than 90% efficiency as per the ASHRAE test standards for dry particulate. The collection cells shall be in Single Pass arrangement to provide for maximum collection efficiency.

10 IONIZING COLLECTION CELL

Ionizing-Collecting cell(s) shall be of one-piece construction minimum 13.38" inches deep in direction of airflow. All support framing, end plates and ionizer ground electrodes shall be 0.090 inch thick aluminum. Both repelling and collector plates shall be 0.020 inch thick aluminum, 9.125 inch deep in direction of airflow and rigidly retained in place with tubular spacers and tie rods. Spacing between plates shall be no less than 0.175 inch. Ionizing electrodes shall be heavy duty tungsten wire rigidly supported both vertically and laterally. High voltage support insulators shall be made of Teflon, including center hole, glazed to enhance dielectric strength and retard tracking. Insulators shall be mounted out of the airstream, to reduce contaminant buildup. All high voltage electrical connections within each tier of cells, shall be between cells and automatically made when cells are installed. All electrical connections between unit tiers and high voltage connections between power packs and cells shall be located on the access door end of the cabinet and manually connected for ease of service.

11 POWER SUPPLIES

Power supplies shall be 100% solid state, CE Listed. operate on 200 to 240 VAC, 50 HZ, 1 Phase input and provide a dual high voltage output of (+) 12 to 13 KVDC for the ionizer and (+) 6.0 to 6.5 KVDC for the collector. A regulated output of up to 5.5 MA shall be supplied to maintain the specified collection efficiency. Integrally mounted electrical interlocks shall be provided to prevent access to the high voltage components without first interrupting the primary input power. The power supply shall operate over a temperature range of -32 degrees F to 140 degrees F, be self-protecting and accommodate an LED light indicating the performance status of the ionizing/collecting cell. High voltage output leads shall be sealed and a bleed resistor incorporated to remove stored electrical charge where the power supply(s) are de-energized. Module of capacity above 3000 CFM shall be equipped with Pulse width modulating (PWM) to maintain the specified collection efficiency by maintaining a constant charge in the event of Low/High Voltage from source thus ensuring that the unit functionality is not affected with these voltage fluctuations. Power Consumption should not be more than 50 watts per ESP cell.

All power supply components shall be designed for ease of mounting and servicing. High voltage power cables shall be of one continuous length, splicing is not acceptable.

12 Arc Suppression & Auto Restart

The power pack shall incorporate a short circuit arc protection with automatic power restoration system to prevent overload. Should arcing take place (due to collection cells being loaded with contaminants or should there be a fault in the unit), the power pack shall be able to automatically cut off the supply to stop the arcing and reset after a few seconds. This is to prevent and drastically reduce the risk of fire from continuous arcing.

13 BMS (Building Management System) interface

The power supply (pack) shall have a 2 wire dry contacts (NO/NC) for remote link to Building Management System. This is for performance indication of the air cleaning system. Should there be a fault or if service is required, the dry contacts close and a signal is sent to the building BMS System. Should there be multiple units, all the dry contacts can be looped into a set of signal. This ensures proper monitoring of the status of each unit.

14 PERFORMANCE INDICATOR LIGHTS

There shall be 2 LED lights (Green & Red) installed on the access door of the unit to indicate the status of the air cleaning system.

15 STATIC PRESSURE DROPS

The pressure drop shall not exceed the following (inches H₂O):

| | |
|---------------------------------------|------|
| ESP Section | 0.14 |
| Metal Mesh pre-filter or after filter | 0.10 |

The ESP section must have both an internal pre-filter and an after filter, select and add for each.

External losses for ductwork, exhaust hoods, manufacturing equipment with associated entry losses, kitchen hoods, etc. must be added with the above internal equipment losses to calculate total fan static pressure required.

SECTION VIII : BLOWERS / FANS

1 SCOPE

The scope of this section includes the supply, installation, testing and commissioning of centrifugal blowers, in-line fans, propeller type fans and roof fans (roof extractors) conforming to these Specifications and in accordance with the Drawings and Schedule of Quantities.

2 TYPE

Blowers / Fans unit shall be of the type as identified in Drawings and included in Schedule of Quantities.

3 CAPACITY

The air delivery of blowers / fans shall be as per Drawings and Schedule of Quantities.

4 CENTRIFUGAL BLOWER

Centrifugal blower / fan shall be DWDI / SWSI Class I construction arrangement 3 (i.e. bearings on both the sides) or shall be as per bill of quantity, squirrel-cage induction motor, including accessories i.e. MS base, V-belt drive, belt guard and vibration isolators. Direction of discharge and motor position shall be as per the Approved-for-Construction shop drawings.

- a. Blower housing shall be constructed of 14 gauge sheet steel having welded construction. It shall be reinforced and supported by structural angles. Split casing shall be provided on larger sizes of fans. Packing shall be provided throughout split joints as per manufacturer standards to make it air-tight.

Galvanized wire mesh inlet guards of 18 gauge shall be provided on both inlets. Direction of rotation shall be clearly marked on the housing. Housing shall be provided with standard cleanout door with handles and neoprene gasket.

- b. Fan wheel and housing shall be statically and dynamically balanced. Fan Wheel shall be backward-curved non-over loading type. Fan outlet velocity for fans up to 450mm die meter, shall not exceed 550 meter/minute and fan speed not exceeding 1450 rpm. Fans above 450 mm die, shall have the outlet velocity within 700 meter/minute and fan speed not exceeding 1000 RPM. High static pressure fan speed shall be as per manufacturer.
- c. Shaft shall be constructed of steel, turned, ground and polished.
- d. Bearings: shall be of the ball-bearing type mounted directly on the fan housing. These shall be especially designed for quiet operation and shall be of the self-aligning, oil / grease pack pillow block type.
- e. Motor: Blower motor shall be energy efficient and suitable for $415 \pm 10\%$ volts, 50 cycles, 3 phase AC power supply, squirrel-cage, totally enclosed, fan-cooled, having class F insulation. Motor shall be designed especially for quiet operation and motor speed shall not exceed 1440 rpm. Motor name plate horsepower shall exceed brake horsepower by a minimum of 10%. The blower and motor combination selected for the particular required performance shall be of the most efficient (smallest horse power), to minimize the sound level.
- f. Drive to fan shall be through belt/s with adjustable motor sheave. Belts shall be of the oil-resistant type. Drive assembly shall be provided with proper guard.

- g. Vibration Isolation: MS base shall be provided for both fan and motor, built as an integral part, and shall be mounted on a concrete foundation through casing foot type vibration isolators. The concrete foundation shall generally be 150mm above the finished floor level, or as shown in approved-for-construction shop drawings.

5 AXIAL FLOW FAN

Fan shall be complete with motor (direct or belt driven type) motor mount, and vibration isolators. Installation arrangement shall be as per approved for construction shop drawings.

- a. Casing: Fan casing, motor mount and straightening vane shall be of welded steel construction. Motor mounting plate shall be minimum 15 mm thick and machined to receive motor flange. Casing shall have flanged connection on both ends for duct connections. Casing shall have welded support brackets for suspending fan unit from ceiling. Straightening vanes shall be aerodynamically designed for maximum efficiency by converting velocity pressure to static pressure potential and minimizing turbulence. Casing shall be bowdlerized, primed and finish coated with enamel paint.
- b. Rotor: hub and blades shall be cast steel or cast aluminum construction. Blades shall be aero foil shaped shall vary in twist and width from hub to tip for maximum efficiency & to effect equal air distribution along the blade length. Fan blades on the hub shall be statically and dynamically balanced. Extended grease parts for external lubrication shall be provided. The fan pitch control shall be manually readjust able. Upon installation it may require manual readjustment at site, for obtaining actual air flow values, as specified and quoted.
- c. Motor: shall be energy efficient squirrel-cage, totally-enclosed, fan cooled, continuous duty, suitable for $415 \pm 10\%$ volts, 50 cycles, 3 phase AC power supply. It shall be provided with class ' F' insulation. Motor shall be specially designed for quiet operation. The speed of the fans for fans with impeller diameter above 450mm shall not exceed 1000 RPM and 1440 RPM for fans with impeller diameter 450 mm and less. Fan shall be selected for maximum efficiency or minimum horsepower for lowest sound level. Motor conduit box shall be mounted on exterior of fan casing, and lead wires from the motor to the conduit box shall be protected from the air stream by enclosing in a flexible metal conduit.
- d. Drive: From motor to fan shall be provided either directly through motor shaft or through belt drive with adjustable motor sheave and standard sheet steel belt guard. Belts shall be of oil-resistant type.
- e. Vibration Isolation: The assembly of fan and motor shall be suspended from the slab by vibration isolators of rubber-in-shear type.
- f. Accessories: The following accessories shall be provided with all fans:
 - i. Outlet cone for static pressure regain.
 - ii. Inlet cone.

Fans shall be factory assembled and shipped with all accessories factory fitted. Silencers at fans may be provided as per project demand and is included in schedule of quantities.

6 PROPELLER FAN

Propeller fan shall be direct-driven, three or four blade type, mounted on a steel mounting plate with orifice ring.

- a. Mounting Plate shall be of steel construction, square with streamlined venture inlet, reversible for supply applications coated with baked enamel paint. Mounting plate shall be constructed of 12 to 16 gauge sheet steel depending upon the fan size. Orifice ring shall be correctly formed by spinning or stamping to provide easy passage of air without turbulence and to direct the air stream.

- b. Fan Blades shall be constructed of aluminum or steel. Fan hub shall be of heavy welded steel construction with blades bolted to the hub. Fan blades and hub assembly shall be statically and dynamically balanced at the manufacturer's works.
- c. Shaft shall be of steel, accurately ground and shall be of ample size for the load transmitted and shall not pass through first critical speed thru the full range of specified fan speeds.
- d. Motor shall be standard (easily replaceable) permanent split capacitor or shaded pole for small sizes, totally enclosed with pre-lubricated sleeve or ball bearings, designed for quiet operation with a maximum speed of 1000 rpm for fans 60 cm dia or larger and 1440 rpm for fans 45 cm dia and smaller. Motors for larger fans shall be suitable for $415 \pm 6\%$ volts, 50 cycle's 3 phase power supply, and for smaller fans shall be suitable for $220 \pm 6\%$ volts, 50 cycle's single phase power supply. Motors shall be suitable for either horizontal or vertical service as indicated on Drawings and in Schedule of Quantities.
- e. Accessories: The following accessories shall be provided with propeller fans :
 - i. Wire guard on inlet side and bird screen at the outlet.
 - ii. Fixed or gravity louvers built into a steel frame at the outlet.
 - iii. Regulator for controlling fan speed for single phase fan motor.
 - iv. Single phase preventer for 3 phase fan.

7 ROOF MOUNTED FAN

Roof mounted fan shall be propeller type or centrifugal fans, direct driven or belt driven as shown on drawing and in Schedule of Quantities, complete with motor drive, and casing / housing with weather-proof cowl.

- a. Casing: shall be constructed of 16 gage steel sheet. The housing shall have an adjustable flange to facilitate installation and shall be especially adapted to receive fan, motor, and drive. The housing shall have a low silhouette. For belt driven units, motor shall be installed in ventilated water proof housing outside the air stream. The discharge cowl shall be hinged along one edge for easy access to motor and drive, for inspection and maintenance. The entire assembly shall be weatherproof and raised from the roof terrace sufficiently to prevent down flow of rain water accumulated on the terrace. 18 gage galvanized steel mesh bird screen shall be provided on all discharge cowls around the outlet area.
- b. Fans: shall be backwardly inclined centrifugal wheel or propeller type as required, designed for maximum efficiency, minimum turbulence and quiet operation. Fan shall be statically and dynamically balanced.
- c. Motor: shall be shaded pole, of split capacitor type with lubricated sleeve or ball bearings, designed for quiet operation. Bearings shall be designed for vertical mounting. Motor name-plate horse-power shall be such that the motor shall not be overloaded in the entire range of rated speed. Motor and fan assembly shall be easily removable. Motor power supply characteristic and maximum speed shall be as specified for propeller fans and as indicated in the Schedule of Quantities.
- d. Fan Bearings: shall be heavy duty, self-aligning sleeve/ball bearings designed for thrust load and sealed for grease retention.
- e. Back draft Damper: Where called for in the Schedule of Quantities, roof-mounted fan shall be equipped with a rattle-free backward raft damper to prevent air from re-entering the fan when fan is not in operation, thus sealing completely in closed position. Damper shall be chatter proof under all conditions.
- f. Vibration Isolation: The motor and fan assembly shall be isolated from the base with vibration isolators.

8 PERFORMANCE DATA

All fans shall be selected for the lowest operating noise level. Capacity ratings, power consumption, with operating points clearly indicated, shall be submitted and verified at the time of testing and commissioning of the installation.

9 TESTING

Capacity of all fans shall be measured by an anemometer. Measured air flow capacities shall conform to the specified capacities and quoted ratings. Power consumption shall be computed from measurements of incoming voltage and input current.

SECTION IX : EXPANSION TANK

1 CLOSED EXPANSION TANK

The closed expansion tank will be of M.S. construction with interchangeable EPDM-BUTYL rubber membrane. The expansion tank shall be complete with safety relief valve and pressure gauge.

The tank will be of pressure rating to suit the system pressure and will be sized to adequately compensate for water expansion due to operating temperature variations. The tank shall be fabricated as per IS 2825-1969 for "non-red pressure vessels" and the ranges shall be as per IS 6392-1971.

For chilled water application, it will be insulated with 50mm thick insulation to the specifications and cladded with 26G-aluminium cladding.

The expansion tank shall be supplied along with pressurization unit. The pressurization unit shall consist of two nos. (1 working + 1 stand-by) high pressure pumps of suitable pressure rating mounted on M.S. frame, complete with interconnecting piping, isolation valves, NRV, Y-strainer, pressure gauge, pressure transmitter, auto-logic panel (IP 55) with dry-run protection, electrical MCB and interconnecting wiring.

The unit shall be housed in powder-painted canopy suitable for external installation, if required.

2 AIR SEPARATORS

The centrifugal air - separator will be of M.S. construction with flanged connections. The air separator will be adequately sized to achieve maximum air-separation. It will be provided with a high capacity super-vent at the top. The shell shall be fabricated as per IS 2825-1969 for "non-fired pressure vessels" and the ranges shall be as per IS 6392-1971.

For chilled water application, it will be insulated with 50 mm thick insulation to the specifications and cladded with 26G-aluminium cladding.

SECTION X : ELECTRO-CHEMICAL TREATMENT SYSTEM

System Description:

Electro-chemical treatment system for cooling tower works in side stream without disturbing Cooling Tower Operations. The system should deploy an electrolysis reaction with controlled constant DC current which creates Electrolysis Reaction generating (-OH) Ions at Cathode which creates high PH on the walls of cathode, this results in precipitation of calcium and magnesium salts present in the water into the electrolytic reactor and Chlorine gas is generated at anode which acts like Biocide and avoids bacterial growth and algae formation. The system should be equipped with Automatic Self Cleaning Mechanism & Automatic Blow down Control. The proposed system should be manufactured and complied with ISO 14001:2015, ISO 9001:2015. The system must be CE + RoHS compliant and in accordance with UL standards. The proposed system should minimize blow down water consumption up to 70%. No/Zero Chemicals uses for cooling tower circuit, technology must fall under green technology initiatives, the system must avoid algae and micro-bacterial formation in water or surface of Pipe/ CT/ fills. Self-treatment of Corrosion in the cooling water circuit, must extend life of the Cooling Tower Fills. The system must have below components:

- 1. Electrolytic Reactor:** An electrolytic cell has three component parts: an electrolyte and two electrodes (a cathode and an anode). The electrolyte is usually a solution of water or other solvents in which ions are dissolved. Molten salts such as sodium chloride are also electrolytes. When driven by an external voltage applied to the electrodes, the ions in the electrolyte are attracted to an electrode with the opposite charge, where charge-transferring (also called faradaic or redox) reactions can take place.
- 2. Automated Scrapper mechanism for reactor cleaning:** The Reactors need frequent cleaning and the system must be equipped with self-cleaning reactors to ensure zero down time and manual interventions.
- 3. Automatic Blow down control:** Automatic Blow Down feature allows only the required quantity blow down based on the real time monitoring of Chlorine, PH and conductivity. This feature in system ensures the drain valve operation and need no manual interventions.
- 4. Side screen Filter:** The Side Screen filter is provided in side stream water coming out thru electrolyte process. This filter eliminates any particle in water to travel across. The possibility of scraped debris and substance are being avoided with the feature.
- 5. Automatic Back wash:** Automatic Back wash is a feature of Side screen filter in which the filters are being cleaned automatically with the feedback of pressure drop. The motorized valves are provided to reverse the direction of water and the cleaning of side screen filter being taken care automatically.
- 6. Control Panel:** This makes system Industrial 4.0 compliant and to be future ready (Optional Feature). The panel is monitoring status of individual cooling tower and modulating the water flow control valves. The real time monitoring of PH, TDS and Conductivity happen and any common to modulate DC current/Voltage/Drain/Back Wash/Scraping and self-cleaning is initiated automatically. The panel will have 7" inches touch display with graphical representation.
- 7. Skid with Pumps & Valves:** The Common Skid should have pipe and flanges of MS material IS2062 Grade B. All welding of Skid shall be performed by Argon/ARC weld. The Skid frame should be of MS material of same IS2062 grade B. The Skid valves should be of diaphragm type or equivalent with all joints to be flanged and bolted. The valves used for injection and collection from respective chillers shall be of actuator type with minimum IP54 protection and less than 10s running time for open or close function with NEMA –II protection. The valve should be suitable to work in high humid environment up to 95% (Non-condensing) RH. All fasteners shall be of high-tension grade 9.8, 10.9, 12.9.

8. Scope of Supply:

The scope of supply would be as given below:

1. Self-Cleaning Reactor with Anode and Cathode
2. Control Panel with PLC & Multicolor HMI
3. Circulation Pump
4. PH, TDS, Conductivity Meter for real time monitoring
5. Side Screen Filter with Pressure differential monitoring
6. Automatic Back wash & Blow-down Arrangement
7. Self-Scrapping mechanism
8. Motorized Valve
9. Manual Valves
10. Flow Switch and Pressure Gauge
11. Skid & Accessories

SECTION XI: INTELLIGENT ANTI FOULING CONDENSER SYSTEM/ SMART AUTOMATIC TUBE CLEANING SYSTEM

Control Panel:

The Control Panel system shall include IoT Ready, Industry 4.0 compliant device. The Panel should have minimum 7" Touch Screen Graphical HMI which will log the real time data related to chiller energy (KWH), capacity (TR), Chiller Water Flow monitoring, Water Temperature profile on evaporator and condenser both, compliances and graphical representation of historic summary which shall be displayed on the Mobile Application with unlimited user access on cloud based system. The data can also be retrieved in XL or PDF Format. The HMI should have depiction of injection and collection cycle. The alarms and faults shall be indicated on the screen in case of any issue in operation. Display must be Touch type, graphical presentation, and with multi-level security passwords with defined functional authorities. The Energy Meter, Flow Meter, Temperature Sensor should be suitable to the site requirement and as per OEM Standards.

Ball Trap:

The ball trap shall be mounted between two flanges -(BS Table 10 E) Grade B, 15 days 100lbs capacity, at the outlet line of the condenser. The casing shall be made from MS material of IS2062 Grade B. The Ball trap shall have epoxy based finished paint. The screen inside is made from stainless steel SS304L perforated metal sheet.

The Ball Trap should have pressure drop of less than 800 mm of WC. The body of the Ball trap shall be of size as nozzle or flange size or the pipeline size in which Ball trap must be installed. **For example:** if the pipeline size is 10 inches the Ball trap body should be of 10 inches.

The Ball Trap shall have Race Face Flange with gasket on only inner dial of pipe and should not be on the entire flange dia to avoid leakage.

Ball Collector:

The ball Collector shall be made of suitable size capable of storing all the sponge balls required and should be made from MS material of IS2062 Grade B. The Ball collector should have epoxy based finished paint. The Ball Collector should have a sight glass for monitoring the balls. Toughened glass should be used and should be mounted by Allen key fasteners or SS nut bolt.

Skid with Pumps & Valves:

The Common Skid should have pipe and flanges of MS material IS2062 Grade B. All welding of Skid shall be performed by Argon weld. The Skid frame should be of MS material of same IS2062 grade B. The Skid valves should be of diaphragm type or equivalent with all joints to be flanged and bolted. The valves used for injection and collection from respective chillers shall be of actuator type with minimum IP54 protection and less than 10s running time for open or close function with NEMA –II protection. The valve should be suitable to work in high humid environment up to 95% (Non-condensing) RH. All fasteners shall be of high-tension grade 9.8, 10.9, 12.9.

Working Principle - Activity Sequence

The operation is based on the circulation of the sponge ball through the condenser tube. The sponge ball must be pushed to the condenser inlet in **not more than 5 seconds** by a **high flow of water (min.7L/S)** which can be produced by a high-pressure source **at least 2 bar** higher than the injection point at the condenser inlet. The source can be obtained by a single water injection pump in water injection system. Water injection system will be operated by a PLC controller which is pre-programmed to execute the cleaning process in two consecutive steps. There shall be ball injection cycle and ball collection cycle. The proposed system should be manufactured and complied with ISO 14001:2015, ISO 9001:2015. The system must be CE + RoHS compliant and in accordance with UL standards.

1. STEP 1:

The PLC shall activate the cleaning process by detecting the on/off status of the corresponding chiller (or condensing water isolating valve). If the chiller is on, the PLC shall command the control valves to open to manage the injection. The check valves shall be installed in the location as shown on the scheme above and as close as possible to the collector to ensure correct water flow direction during the injection cycle and the collection cycle.

2. STEP 2:

The injection cycle, the PLC shall command the injection control valve to open for couple of seconds (the collection control valve kept closed in the cycle) and then close. The water pressure from the pump shall be used to push the water inside the injector to the collector and force all balls in the collector to the condenser.

3. STEP 3:

The cycle's hall is completed until the ball passing through the condenser where it should clean all the deposits on internal surface of the tubes. After leaving condenser the balls shall be trapped inside the ball trap unit.

4. STEP 4:

After the injection cycle is finished, the PLC shall command the collection control valve to open for couple of seconds (the injection control valve kept closed in the cycle) and then close. The negative pressure shall let the ball return from the ball trap unit back to the collector where the rinsing of the balls is carried out and then water is discharged to the outlet header of Condenser which goes to cooling tower. The ball shall wait in the collector until the next injection cycle. The time of the collection cycle is normally pre-set at 27 minutes.

5. A single pump should be on skid and shall be running during injection and collection cycles.

6. The pressure drop across ball trap shall not be more than 800mm.

7. The Valves shall give feedback to Control PLC of functioning.

8. The Control PLC shall raise an alarm in case of any malfunctioning of system

9. The total time of the whole cycle (injection and collection cycle) shall be 3 - 4 minutes.

10. A maximum number of 4 Condensers should be controlled by single skid and Control Panel. If the number of Condenser increases beyond 4, additional Skid with Control Panel should be considered and should be followed consequently.

SECTION XII : PIPING

1 SCOPE

The scope of this section comprises the supply and laying of pipes, pipe fittings and valves, testing and balancing of all water and refrigerant piping required for the complete installation as shown on the Drawings. All piping inclusive of fittings and valves shall follow the applicable Indian 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.

2 PIPE SIZES

Pipe sizes shall be as required for the individual fluid flows. Various pipe sizes 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.

3 CHILLED WATER PIPING

- a. All chilled water pipes and all fittings shall be Mild Steel (MS) Class 'C' (Heavy Class) conforming to relevant BIS-1239 Code. Factory rolled pipes between 250 mm to 600 mm diameter shall have 8 mm wall thickness. All jointing in the pipe system shall generally be by welding, unless otherwise mentioned, or directed at site. All welding shall be done by qualified welders and shall strictly conform to BIS Code of practice for manual metal arc, welding of Mild Steel.

Welder shall be having minimum 5 years of experience. First butt weld of each welder shall be fully radiographed for testing purposes. Upon approval of welding joints the concerned welder shall be allowed to carry further welding of pipes. Rest of the welds shall have 100% visual inspection.

- b. All welded joints (except pipe welded end-to-end) shall be made by use of one-piece welding flanges, caps, nozzles, elbows, branch outlets and tees of approved make. Cut samples shall be submitted for approval, if directed. All such fittings etc., shall be of a type which maintain full wall-thickness at all points, simple radius and fillets, and proper bevels or shoulders at ends. All job welding shall be done by the electric arc welding process in accordance with the following :
 - All joints shall have 45 degree bevel type, pipe mill-beveled or machine-beveled by the contractor.
 - All scale and oxide shall be removed with hammer, chisel or file and bevel left smooth and clean.
 - Pipe lengths shall line up straight with abutting pipe ends concentric.
 - Both conductors from the welding machine shall be extended to locations at which welding work is being done. The leads from welding machine to location of welding work shall be held together with tape or other approved means so as to prevent induced current in structural steel, in piping or in other metals within the building. The ground lead shall be connected to length of pipe through joints in pipe, structural steel of building or steel pipe supports.
- c. All pipes and their steel supports shall be thoroughly cleaned and given one primary coat of epoxy paint over epoxy primer before being installed. For vibration isolators remolded polyurethane pipe sections of 160 Kg/m³ density with adhesive shall be fixed between pipe and MS support. 10 mm thick MS 'U' clamp with resist flex shall be fixed on the pipe so that the pipe is kept in position. All welded piping shall be subject to the approval at site.

- d. Fittings shall be malleable casting of pressure rating suitable for the piping system. Fittings used on welded piping shall be of the weldable type. These shall form part of piping and are not separately identified in Schedule of Quantities.
- e. Tee-off connections shall be through equal or reducing tees, otherwise ferrules welded to the main pipe shall be used. Drilling and tapping of the walls of the main pipe shall not be resorted to.
- f. Ball and butterfly valves conforming to the following specifications shall be provided as shown on Drawings :

| Size | Construction | Ends | Type |
|----------------|-------------------|---------|-----------|
| 15 to 32 mm | Brass ASTM B62 | Screwed | Ball |
| 40 mm and over | Body Cast iron, | Wafer | Butterfly |

Type and requirements shall be as indicated in Schedule of Quantities. Valves shall have non-rising spindles unless specified otherwise and shall be suitable for PN 16 rating.

- g. Butterfly valves shall perform the function of isolating valves. Butterfly valves shall have cast iron body with black nitrile rubber seat and shall be suitable for PN16 rating. All butterfly valves shall be provided with locking devices. Valves 250 mm and above dia shall be gear driven.
- h. Automatic balancing valves shall automatically control flow rates with + 5% accuracy. Valve control mechanism shall consist of a stainless steel cartridge with a ported cup and coil / helical spring to avoid corrosion. Four operating ranges shall be available with the minimum range requiring less than 14 kPa to actuate the mechanism. Manufacturer shall provide independent laboratory tests verifying assurance of performance.
- i. Manual double regulating balancing valves shall be provided at chiller, condenser, various tap-offs and each AHU outlet line as indicated in Schedule of Quantities. These valves shall have built-in pressure-drop measuring facility to compute flow rate across the valve. The test cocks shall be long enough to protrude out of pipe insulation. To enable accurate and practical operation, measurement of flow and differential pressure shall be made with a computerized balancing instrument which shall enable the operator to read the flow directly without the use of diagrams or tables. In addition to measuring flow rate, differential pressure and temperature, computerized balancing instrument shall have a computer programmer to provide the following functions:
 - i. To balance the HVAC installation and calculate the necessary valve settings, based on system measurements.
 - ii. To store the results of balancing.
 - iii. To log measured values from a valve (differential pressure, flow rate or temperature).
 - iv. To printout saved data in computerized measurement protocol (CMP) consisting of :
 - Name and size of Balancing Valve (BV)
 - Presetting position of BV
 - P at BV
 - Flow at BV
 - Design Flow

- j. Flanges shall be of approved make. The supply of flanges shall form part of piping (not separately identified in Schedule of Quantities) and shall also include supply of bolts, washers, nuts and suitable asbestos fiber / rubber insertion gaskets (minimum 3 mm thick).
- k. All ball valves and ball valves with Y strainer shall be bronze forged body construction with chrome plated bronze ball and handle of stainless steel constructions. These are separately identified in Schedule of Quantities.
- l. Non return valves shall be dual plate check valve provided as shown on the Drawings, and identified in Schedule of Quantities conforming to relevant Codes and in accordance with the following Specifications :

| Size | Construction | Ends |
|------------------|--|---------|
| 50 to 150 mm | Body cast iron, Gun metal plate. | Flanged |
| 200 mm to 450 mm | Body cast iron, plate Carbon steel with 13%chrome overlay. | Flanged |

The spring and hinge/stop pin shall be SS304 and bearing PTFE material. Valves shall be PN 16 rating.

- m. Strainers shall be 'Y' type or Pot Strainer suitable for PN 16 rating as shown on drawings and included in BOQ. 'Y' Strainer shall be fabricated out of MS 'C' class pipe two sizes higher than that of Strainer pipe size. Flanges as per B.S. 10 shall be provided at inlet and outlet connectors. The body shall be hot dip galvanized. Permanent magnet shall be provided in the body of the Strainer to arrest MS particles. Filter element shall be of nonmagnetic 20 gage SS sheet with 3 mm perforation. Strainers shall be provided at inlet of each Air Handling Unit and Pump as shown in drawings and included in BOQ.

Pot Strainers body shall be fabricated out of MS plate IS 226. Thickness of sheet shall be as per size of the strainer chamfered pipes with flanges shall be provided at inlet /outlet connections of the strainer. The tangential entry of water shall create a centrifugal action and due to velocity shall separate sediments and deposit on the inner surface of Filter Element and at bottom of the Strainer. Butterfly valves shall be provided at inlet / outlet connections as shown in drawing and included in BOQ. The strainer body shall have two separate chambers properly sealed to avoid mixing of filtered and unfiltered water.

A powerful magnet shall be provided in the body to arrest MS particles. Filter element of Pot Strainer shall be of nonmagnetic 18 gage SS sheet properly reinforced to avoid damage of the element. A cone with sufficiently large drain pipe with butterfly valve shall be provided at the bottom chamber to flush-out foreign particles.

This arrangement shall avoid frequent opening of Pot Strainer for cleaning of filter element. Gage connection shall be provided at inlet and outlet connection.

A set of MS flanges with tongue and groove arrangement and neoprene rubber gasket shall be provided on the top cover and Pot Strainer flange with sufficient bolts and nuts to make the joint water tight. Bearing loaded tope cover lifting and swinging arrangement shall be provided.

The Pot strainer body shall be properly de-rusted and epoxy coated from inside and outside. Manufacturers Test Certificate shall be provided with each Pot Strainer.

Size of various Pot Strainer, Filter Element and Thickness of MS sheet shall be as under:

| Pipe size(mm) | Pot Dia(mm) | Pot ht.(mm) | Element Dia (mm) | Element Ht(mm) | MS Plate Thickness (mm) |
|---------------|-------------|-------------|------------------|----------------|-------------------------|
| 50 | 300 | 400 | 200 | 240 | 6 |
| 80 | 350 | 450 | 250 | 250 | 6 |
| 100 | 450 | 500 | 300 | 280 | 6 |
| 125 | 500 | 600 | 330 | 340 | 8 |
| 150 | 540 | 700 | 360 | 390 | 8 |
| 200 | 610 | 815 | 400 | 470 | 8 |
| 250 | 800 | 955 | 550 | 510 | 8 |
| 300 | 1000 | 1105 | 750 | 580 | 8 |
| 350 | 1190 | 1300 | 895 | 678 | 12 |
| 400 | 1350 | 1500 | 1020 | 785 | 12 |
| 450 | 1518 | 1700 | 1060 | 890 | 12 |
| 500 | 1698 | 1900 | 1160 | 990 | 12 |
| 600 | 2000 | 2200 | 1500 | 1160 | 12 |

Each Port strainer shall be provided with a Test Certificate.

- n. All chilled water piping and fittings shall be pressure tested, painted and then insulated as described under the section "Insulation".
- o. Grooved coupling: Grooved coupling shall have 3 main parts viz. Housing, Gasket and bolting arrangement. Housing shall be made out of ASTM-A 536 Grade 65-45-12. The housing key shall engage into the grooves around the full pipe circumference, securing the pipe ends together with positive grip. Housing shall be designed to provide optimum combination of pressure, stress relief and end load conditions while maintaining reasonable weight. Gasket shall be of high sealing efficiency and shall be able to withstand upto (-) 0.35 Bar pressure. Bolt shall confirm to ASTM A183, while nut shall confirm to ASTM A194. Nut-bolt shall be electro-galvanized.

All pipe / equipment connections within the plant room shall be with Victaulic couplings.

4. GROOVED PIPE JOINTING SYSTEM

A. References:

1. American Society for Testing Materials (ASTM)
 - a. ASTM A-53 – Pipe, Steel, Black and Hot-Dipped Zinc Coated, Welded and Seamless.
 - b. ASTM A-183 – Carbon Steel Track Bolts and Nuts
 - c. ASTM A-234 – Standard Specification For Piping Fittings or Wrought Carbon Steel and Alloy Steel.
 - d. ASTM A-449 – Quenched and Tempered Steel Bolts and Studs
 - e. ASTM A-536 – Ductile Iron Castings
 - f. ASTM F-1476 - Standard Specification for Performance of Casketed Mechanical Couplings for Use in Piping Applications
2. American Society of Mechanical Engineers
 - a. ASME B16.9 – Factory Made Wrought Butt Welded Fittings
 - b. ASME B31.1 – Chemical Plant and Petroleum Refining Piping
 - c. ASME B31.9 – Building Services Piping
3. American Water Works Association
 - a. AWWA C-606 – Grooved and Shouldered Joints

B. Quality Assurance

1. All grooved components (including couplings, fittings, valves and accessories) to be supplied by one manufacturer. Grooving tools shall be of the same manufacturer as the grooved components.

C. Grooved Mechanical Couplings for Joining Carbon Steel Pipe

1. Grooved Mechanical Couplings: Manufactured in two segments of cast ductile iron, conforming to ASTM A-536, Grade 65-45-12. Gaskets shall be pressure-responsive synthetic rubber, grade to suit the intended service, conforming to ASTM D-2000. (Gaskets used for potable water applications shall be UL classified in accordance with ANSI/NSF-61 for potable water service.) Mechanical Coupling bolts shall be zinc plated (ASTM B-633) heat treated carbon steel track head conforming to ASTM A-449 and ASTM A-183, minimum tensile strength 110,000 psi (758450 kPa) as provided standard Victaulic.
 - a. Rigid Type: Coupling housings with offsetting, angle-pattern bolt pads shall be used to provide system rigidity and support and hanging in accordance with ANSI B31.1, B31.9, and NFPA 13.
 - b. Flexible Type: Use in locations where vibration attenuation and stress relief are required. Flexible couplings may be used in lieu of flexible connectors at equipment connections. Three Couplings shall be placed in close proximity to the vibration source.
 1. Flange Adapters: For use with grooved end pipe and fittings, for mating to ANSI Class 150 flanges.
 2. Grooved couplings shall meet the requirements of ASTM F-1476.
 3. Gasket: Synthetic rubber, wide width, conforming to steel pipe outside diameter and coupling housing, manufactured of elastomers as designated in ASTM D-2000.
- D. Grooved End Fittings: Fittings shall be cast of ductile iron conforming to ASTM A-536, Grade 65-45-12, forged steel conforming to ASTM A-234, Grade WPB 0.375" wall (9.53 mm wall), or fabricated from Std. Wt. Carbon Steel pipe conforming to ASTM A-53, Type F, E or S, Grade B. Fittings provided with an alkyd enamel finish or hot dip galvanized to ASTM A-153. Zinc electroplated fittings and couplings conform to ASTM B633.
 1. Grooved Hole-Cut Branch Outlets:
 - a. Bolted Branch Outlet: Branch reductions on 2"(DN50) through 8"(DN200) header piping. Bolted branch outlets shall be manufactured from ductile iron conforming to ASTM A-536, Grade 65-45-12, with synthetic rubber gasket, and heat treated carbon steel zinc plated bolts and nuts conforming to physical properties of ASTM A-183.
 - b. Strapless Outlet: 1/2"(DN15) or 3/4"(DN20) NPT outlet on 4" (DN100) and larger header sizes rated for 300 PSI (2065 kPa).
 - c. Strapless Thermometer Outlet: To accommodate industrial glass bulb thermometers with standard 1-1/4"-18 NEF 2B extra fine thread and 6" (152mm) nominal bulb length on 4" (DN100) and larger header sizes rated for 300 PSI (2065 kPa).

5. COLD WATER AND DRAIN PIPING

- a. All pipes to be used for cold water (makeup), drain, condensate drain and fittings shall be galvanized steel class 'B' (medium class) conforming to relevant BIS Codes.
- b. All jointing in the pipe system shall be by screwed joints and/or by screwed flanges using 3 mm 3 ply rubber insertion gaskets. Pipe threads and flanges shall be as per relevant BIS Codes.
- c. All pipes supports shall be mild steel, thoroughly cleaned and given one primary coat of red oxide paint before being installed.
- d. Fittings shall be galvanized steel 'medium class' malleable casting of pressure rating suitable for the piping system. Flanges shall be of approved make. Supply of flanges shall include bolts, nuts, and gaskets as required. Sufficient number of flanges and unions shall be provided for future cleaning and servicing of piping. Tee-off connection shall be through equal or reducing tees. All equipment and valve connections, or connections to any other mating pipes shall be through flanges required for the mating connections. Fittings & flanges shall form part of piping and are not separately identified in Schedule of Quantities.
- e. Gate valves, globe valves, check valves and strainers shall be similar to those specified for chilled, condensing and hot water piping.
- f. For proper drainage of AHU Condensate, 'U' trap shall be provided in the drain piping.
- g. All condensate drain piping shall be insulated and painted as per the section "Insulation" as indicated in Schedule of Quantities.

6. REFRIGERANT PIPING

- a. All refrigerant pipes and fittings shall be hard drawn copper tubes and wrought copper / brass fittings suitable for connection with silver solder / phos-copper.
- b. All joints in copper piping shall be sweat joints using low temperature brazing and / or silver solder. Before joining any copper pipe or fittings, its interiors shall be thoroughly cleaned by passing a clean cloth via wire or cable through its entire length. The piping shall be continuously kept clean of dirt etc. while constructing the joints. Subsequently, it shall be thoroughly blown out using carbon dioxide / 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 be installed 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 be MS heavy duty pipe in pipe type & without any joint in 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 / carbon dioxide at a pressure of 20 kg per sq. 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 cm of mercury and held for 24 hours. Vacuum shall be checked with a vacuum gage.
- h. All refrigeration piping shall be installed strictly as per the instructions and recommendations of air conditioning equipment manufacturer.

7. PIPING INSTALLATION

- a. Design Drawings indicate schematically the size and location of pipes. The Contractor, on award of the work, shall prepare detailed shop drawings, showing the cross-section, longitudinal sections, details of fittings, locations of isolating and control valves, drain and air valves, and all pipe supports. He must keep in view the specific openings in the building through which pipes are designed to pass.
- b. Piping shall be properly supported on, or suspended from, stands, clamps, and hangers as specified and as required. The Contractor shall adequately design all the brackets, saddles, anchors, clamps and hangers and be responsible 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 resist flex sheet.
- c. Pipe supports shall be of steel, adjustable for height and epoxy painted over epoxy primer coated with rust preventive paint and finish coated black. Where pipe and clamps are of dissimilar materials, a gasket shall be provided in between. Spacing of pipe supports shall not exceed the following:

| Pipe size | Spacing between supports | Rod Size |
|--------------|--------------------------|----------|
| Upto 12 mm | 1.5 Meter | 10 mm |
| 15 to 25 mm | 2.0 meter | 10 mm |
| 30 to 150 mm | 2.0 meter | 10 mm |
| Over 150 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 resist flex pads between the cleat and channel. U clamps with resist flex sheet shall be provided to keep the pipe in position.
- e. Bull heading in water/refrigerant piping shall be avoided.
- f. Pipe sleeves at least 3 mm thick, 50 mm / 100 mm larger in diameter than condenser / chilled water pipes respectively shall be provided wherever pipes pass through **retaining** wall and slab. Annular space shall be filled with fiberglass 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 gage metal sheet shall be provided between the insulation and the clamp, saddle or roller, extending at least 15 cm on both sides of the clamp, saddles or roller.
- i. All piping work shall be carried out in a workmen like manner, causing minimum disturbance 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.
- j. Cut-outs in 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.
- k. The Contractor shall make sure that the clamps, brackets, clamp saddles and hangers provided for pipe supports are adequate. Piping layout shall take due care for expansion and contraction in pipes and include expansion joints where required.

- l. All pipes shall be accurately cut to the required size in accordance with relevant BIS Codes, edges beveled and burrs removed before laying. Open ends of the piping shall be closed as the pipe is installed to avoid entrance of foreign matter. Where reducers are to be made in horizontal runs, eccentric reducers shall be used for the piping to drain freely. In other locations, concentric reducers may be used.
- m. Flanged inspection pieces 1.5 meters long, with bolted flanges on both ends, shall be provided no more than 30 meters centers, or where-ever shown in Approved-for-Construction shop drawings, to facilitate future cleaning of all welded pipes.
- n. All buried pipes shall be cleaned and coated with zinc chromate primer and bitumen paint, and placed on concrete blocks with PUF saddles dipped in bitumen at every 2 meters and wrapped with three layers of fiber glass tissue, each layer laid in bitumen.
- o. Insulated buried pipes shall be cleaned, derusted, then coated with rust-resistant primer and placed on concrete blocks with PUF saddles dipped in bitumen at every 2 meters. Insulation shall be applied as per the section "Insulation", wrapped with GI wire and covered with polyethylene sheet. Two coats (each 6 mm thick) of cement plaster shall be applied over chicken wire mesh lath. Where indicated in Schedule of Quantities, buried insulated pipes shall be water-proofed using coat of Shalibond, or approved adhesive, over the plastered surface; wrapping one layer of fiber glass RP tissue and one layer of roofing tar felt with sufficient overlaps, set and sealed with the adhesive, held in position by 16 gage G.I wire tied at 15 cm intervals.
- p. Auto purge valves shall be provided at all highest points in the piping system for venting air. Air valves shall be 15 mm pipe size with screwed joints.

Discharge from the air valves shall be piped through an equal sized mild steel or galvanized steel pipe to the nearest drain or sump. These pipes shall be pitched towards drain points.

8. PRE-INSULATED PIPES

Pre insulated pipes, as called for in schedule of quantities shall be sourced from the factory in length of minimum 6m. Metered dose of Polyurethane foam shall be injected in annular space between pipe OD and outer jacket to achieve average density of 36 Kg/m³. After expanding, homogenous foam shall be formed between the cavity with no air gaps. Suitability of temperature range shall be from (-) 20°C to 120° C.

Outer jacket shall be of GI / AL / SS304 as indicated in schedule of quantities.

9. PRESSURE GAGES AND THERMOMETERS

- a. Pressure gages as specified under section "Automatic Controls and Instruments" shall be provided at suction and at discharge of each pump, at chilled water supply and return at each air handling unit, at each chillers and condenser, and as shown on the Drawings and included in Schedule of Quantities. Care shall be taken to protect pressure gages during testing. Pressure gage sockets on insulated pipes and accessories shall be extended upto insulation to avoid damage of insulation for replacement of gages.
- b. Thermometers as specified under section "Automatic Controls and Instruments" shall be provided at chilled water supply and return at each air handling unit, at each chiller and condenser, and as shown on Drawings and included in Schedule of Quantities.
- c. Thermometers on CHW lines shall be with long stem. Thermometer socket shall be extended upto insulation thickness so that the thermometer shall be removable without damaging the insulation.

10. 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. All piping shall be tested to hydrostatic test pressure of at least two times the maximum operating pressure, but not less than 10 kg per sq. cm gage for a period of not less than 24 hours. All leaks and defects in joints revealed during the testing shall be rectified, retested and gotten approved
- c. Piping repaired subsequent to the above pressure test shall be re-tested in the same manner.
- d. Piping may be tested in sections and such sections shall be securely capped, then re-tested for the entire system.
- e. The Contractor shall give sufficient notice to all other agencies at site, of his intention to test a section or 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. The Contractor shall make sure that proper noiseless circulation of fluid is achieved through all coils and other heat exchange equipment in the system concerned. If proper circulation is not achieved due to air bound connection, the Contractor shall rectify the defective connections. He shall bear all expenses for carrying out the above rectifications including the tearing up and re-finishing of floors and walls if required.
- h. After the piping has been installed, tested and run for at least three days of eight hours each, all insulated exposed piping in plant room shall be given two finish coats, 3 mils each of approved color, conforming to relevant BIS Codes. The direction of flow of fluid in the pipes shall be visibly marked with identifying arrows. For painting of insulated and clad pipes refer to Insulation section.
- i. After testing, all systems shall be chemically cleaned. After cleaning, the pipe work should be rinsed multiples times until the system is neutral. Before handover Owner's site representative shall be provided with certificate of cleaning of pipe systems, signed by the contractor.
- j. The Contractor shall provide all materials, tools, equipment, instruments, services and labor required to perform the test and to remove water resulting from cleaning and after testing.

11. BALANCING

- a. After completion of the installation, all water system shall be adjusted and balanced to deliver the water quantities as specified, quoted, or as directed.
- b. All balancing valves, Automatic control valves and two-way diverting valves shall be set for full flow condition during balancing procedure. Each water circuit shall be adjusted thru balancing valves provided for this purpose; these shall be permanently marked after balancing is completed, so that they can be restored to their correct positions, if disturbed.
- b. Complete certified balancing report shall be submitted for evaluation and approval by Owner's site representative. Upon approval, four copies of the balancing report shall be submitted with the as-installed drawings and completion documents.

12. 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 air conditioning plant room or as directed by Owner's site representative two copies of valve chart. Two additional uncounted 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.

13. MEASUREMENT FOR PIPING

Unless specified otherwise, measurement for piping for the project shall be on the basis of Centre line measurements described herewith.

Piping shall 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, concentric and / or eccentric reducers, inspection pieces, expansion loops etc. The above accessories shall be measured as part of piping length along the Centre line of installed pipes, and no special multiples of pipe lengths for accessories shall be permitted.

The quoted rates for Centre line linear measurements of piping shall include all wastage allowances, pipe supports including hangers, MS channel, PUF supports, nuts, check nuts, vibration isolator suspension where specified or required, and any other item required to complete the piping installation as per the Specifications. None of these items will be separately measured nor paid for.

However, all valves (gate / globe / check / balancing / purge / butterfly / drain etc.), strainers, thermometers, pressure gages shall be separately counted and paid as per their individual unit rates, which shall also include their insulation as per Specifications. Piping measurements shall be taken before application of the insulation.

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

SECTION XIII: AIR DISTRIBUTION

1. SCOPE

The scope of this section comprises supply fabrication, installation and testing of all sheet metal / aluminum ducts, supply, and 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.

2. DUCT MATERIALS

a RAW MATERIALS

Galvanizing shall be Class VII – light coating of zinc, nominal 180 / 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.

b GAUGES, BRACING BY SIZE OF DUCTS

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

For Ducts with external SP upto 250 Pa (25mmWg)

| Rectangular Ducts G. S. | Pressure 250 Pa | | |
|----------------------------|-----------------------------------|--|----------------------|
| | Duct Section Length 1.2 m (4 ft.) | | |
| Maximum Duct Size | Gauge | Joint Type | Bracing Spacing |
| 1–750 mm | 26 | C & SS | Nil |
| 751 – 1000 mm | 26 | 4 Bolt Transverse Duct Connector-E (TDC) with built in sealant | Nil |
| 1001 – 1200 mm | 24 | 4 Bolt TDC - E | Nil |
| 1201 – 1500 mm | 24 | 4 Bolt TDC - H | Nil |
| 1501 – 1800 mm | 22 | 4 Bolt TDC - H | Nil |
| 1801 – 2100 mm | 20 | 4 Bolt TDC - J | Zeebar stiffener 1-S |
| 2101 – 2700 mm | 18 | 4 Bolt TDC - J | Zeebar stiffener 1-S |

Note:- All ducts shall be fabricated with minimum 24 gauge sheet

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.

- 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.
- 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.

- c) All edges to be machine treated using lock formers, flangers and rollers for turning up edges.
- d) Kitchen exhaust ducting shall be with 16 G MS. 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.

4. DUCT CONSTRUCTION

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) All ducts up to 75cms width within conditioned spaces shall have slip and drive (C & S/SS) joints. The internal ends of slip joints shall be in the direction of airflow. Care should be taken to ensure that S/SS Cleats are mounted on the longer side of the duct and Cleats on the shorter side. Ducts and accessories within ceiling spaces, visible from air-conditioned areas shall be provided with two coats of mat black finish paint.
- d) 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.
- e) 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.
- f) 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 and fitted with all necessary inspection doors as required, to give access to all parts of the apparatus. Access doors shall be not less than 45cm x 45cm in size.
- g) 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.
- h) 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.

5. 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 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 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.
- e) 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.
- f) 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.
- g) 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.
- h) Duct shall not rest on false ceiling and shall be in level from bottom. Taper pieces shall taper from top.

6. DAMPERS

- a) Dampers: All duct dampers shall be opposed blade louver dampers of robust 16 G 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.

7. FIRE & SMOKE DAMPERS

- a) All supply and return air ducts at AHU room crossings and at all floor crossings shall be provided with Motor operated Fire & smoke damper of at least 90 minutes rating as per UL555/1995 tested by CBRI. 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.
- b) Fire damper blades and outer frames shall be of 16G galvanized steel construction fitted with 18 gauge extended sleeves on both sides. The damper blade shall be pivoted on both ends using chrome plated spindles in self-lubricated bronze bushes. Stop seals shall be provided on top and bottom of the damper housing made of 16G galvanized sheet steel. For preventing smoke leakage metallic compression seals will be provided.
- 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 or temperature sensor. The fire damper shall also close upon sensing temperature rise in supply air ducts thru the electronic temperature sensor.
- 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 at least 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 its 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 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.
- i) HVAC Contractor shall strictly follow the instructions of the Damper Supplier or avail his services at site before carrying out testing at site.
- j) Fire/smoke damper shall be provided with factory fitted sleeves; however, access doors shall be provided in the ducts within AHU room in accordance with the manufacturer's recommendations.
- k) 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.

8. 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 fire damper.
- b) Fire damper blades shall be one piece folded high strength 16 gage 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 70° C.
- 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), as recommended by the manufacturer, at the time of commissioning of the installation.

9. SUPPLY AND RETURN AIR REGISTERS

Supply & return air registers shall be of either steel or aluminum sections as specified in schedule of quantities. Steel construction registers shall have primer Coat finish whereas extruded aluminum registers shall be either Anodized 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 aluminum volume control damper anodized in matt black shade.

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 aluminum construction with fixed horizontal bars at 15 Deg. inclination & flange on both sides only (none on top & bottom).

The thickness of the fixed bar louvers shall be minimum 5.5 mm 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 aluminum anodized 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 pivot able 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 anodized aluminum in mat black shade.

10. 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. Aluminum diffusers shall be powder coated & made from extruded aluminum section as specified in schedule of quantities.

- a) Rectangular Diffusers shall be steel / extruded aluminum 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 required in specific applications, and as per requirements of schedule of quantities. All extruded aluminum diffusers shall be provided with removable central core and concealed key operation for volume control damper.
- c) Linear Diffuser shall be extruded aluminum 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 aluminum construction anodized in mat black shade.
- d) Slot Diffuser shall be extruded aluminum 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.

11. 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.

12. 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 in excess 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.

13. STEEL WIRE ROPE HANGERS& SUPPORTS:

Wire Hangers shall be used to suspend all static HVAC Air Distribution 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.

C . Wire Hangers should have been independently tested by Lloyds Register. APAVE, TUV, CSA, Chiltern International fire, ADCAS, Intertek, ECA, and SMACNA, approved by CSA and comply with the requirements of DW/144 and BSRIA – wire Rope Suspension systems. Wire rope should be manufactured to BSEN 12385: 2002

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 Hanger Safe Working Loads | | |
|---------------------------------------|---|--|
| size | minimum breaking load of Wire Rope | 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), BSEN12385. Comply with manufacturer's load ratings and recommended installation procedures. Note the testing is done to the minimum breaking load of the wire thus giving a minimum safety factor of 5: 1.

HVAC Supports –Hanger Supports are suitable for: Rectangular duct, Spiral Duct, Oval Duct, Fabric Duct, Desertification fans, Air Conditioning Units, Plenum Boxes, Radiant Panels, Heaters, Fan Coil Units, Diffusers and Chilled Beams.

Ducting Supports:

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. 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 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.

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 at the end of this Section. Any other 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.

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

Refer to manufacturers catalogue and installation guide for further technical information. 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 | Gripple Hanger No. | | Maximum Duct Size (mm) | Gauge | Gripple Hanger No. |
| 1 - 750 | 26 | 1 or 2 | | 1-600 mm | 26 | 1 or 2 |
| 751-1000 | 26 | 2 | | 601-750 mm | 26 | 2 |
| 1001-1200 | 24 | 2 or 3 | | 751-1000 mm | 24 | 2 or 3 |
| 1201 - 1500 | 24 | 3 | | 1001-1200 mm | 22 | 3 or 4 |
| 1501 - 1800 | 22 | 3 or 4 | | 1201-1300 mm | 20 | 3 or 4 |
| 1801-2100 | 20 | 3 or 4 | | 1301-1500 mm | 18 | 4 |
| 2101-2700 | 18 | 4 | | 1501-1800 mm | 18 | 4 |
| | | | | 1801-2100 mm | 18 | 4 |
| | | | | 2101-2250 mm | 18 | 4 or 5 |
| | | | | 2251-2400 mm | 18 | 4 or 5 |
| | | | | 2401-2700 mm | 18 | 4 or 5 |

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.

Desertification fans, Air Conditioning Units, Plenum Boxes, Radiant Panels, Heaters, Fan Coil Units, Diffusers, Cassette units and Chilled Beams.

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:

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. If the MS angle at the bottom if required as per design should be as per following table:

| Longer size of Duct | 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 same manufacturer.

SECTION XIV : INSULATION

1. SCOPE

The scope of this section comprises the supply and application of insulation conforming to these specifications.

2. MATERIAL

Elastomeric Nitrile Rubber

Insulation material for Duct & Pipe insulation shall be anti-microbial closed cell Elastomeric Nitrile Rubber. Thermal conductivity of the insulation material shall not exceed 0.037 W/m²K at an average temperature of 24°C. Density of the nitrile rubber shall be 40-60 Kg/m³. The product shall have temperature range of -40°C to 105°C. The insulation material shall be fire 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 vapor permeability shall be not less than 0.024 per inch (2.48×10^{-14} Kg/m.s.Pa i.e. $\mu=7000$: Water vapor diffusion resistance). The material shall have approval from the Chief Fire Officer.

OR

Chemically Cross-linked Polyethylene Foam

Thermal insulation material for Duct & Pipe insulation shall be anti-microbial closed cell chemically cross linked polyethylene foam. Thermal conductivity of the insulation material shall not exceed 0.032 W/m²K at an average temperature of 25°C. Density of the material shall be 25-30 Kg/m³. The product shall have temperature range of -40°C to 105°C. The insulation material shall be fire rated for Class 1 as per BS 476 Part 7, 1987 for surface spread of flame test and Class O (or alternatively, Class 1) as per BS 476 Part 6 for fire propagation test. Water vapor permeability as per DIN 52615 shall not exceed 0.15ng/Pa.sec.m.

Thermal conductivity of the material shall not be affected by ageing, as per DIN 52616. The material must be tested for ageing effect in an accredited laboratory for a minimum period of five years to satisfy the ageing criteria. The smoke density of the material as per AS-1530.3 shall not exceed 1. There shall be no toxicity in the emitted smoke, both under flaming and non-flaming conditions, as per AITM 3.000 (1993).

The insulation shall comprise of a single layer up to 18 mm thickness.

The material shall be antimicrobial as per ISO 22196, C1338 and ASTM G21-96. There shall be no growth of fungus and mould.

OR

For Duct & Pipe Insulation

Resin Bonded Non-combustible Grade Rockwool

Thermal insulation material **for Duct insulation shall be Rockloyd Resin Bonded non-combustible Grade Rockwool (tested to BS: 476 Parts 4,5,6,7) of density 48 kg/m³** conforming to IS : 8183-1993. Material shall be in the form of slabs or rolls of uniform thickness and laminated with aluminum foil. The 'K' value at 10°C shall not exceed 0.029 Kcal/m.hr°C (0.030 W/mK).The Product shall have temperature range of -10°C to +750°C

Thermal insulation material **for Pipe insulation shall be Rockloyd Resin Bonded Rockwool Pipe section (tested to BS : 476 Parts 4,5,6,7) with or without aluminum foil lamination of density 144kg/m³** conforming to IS : 8183-1993.The 'K' value at 10°C shall not to exceed 0.0370 Kcal/m.hr°C (0.0430 W/mK).The Product shall have temperature range of -10°C to +750°C

OR

For Duct & Pipe Insulation

Isoloyd Nil flame Polyisocyanurate Foam (PIR) Rigid Slab & Pipe section (CFC Free)

Thermal insulation material for duct insulation shall be Isoloyd Nil flame Polyisocyanurate Foam (PIR) Rigid Slab with aluminum foil lamination of density 32 ± 2 kg/m³ and 'K' value shall not exceed 0.020 Kcal/m.hr°C (0.023 W/mK) at mean temperature of 10°C conforming to IS:12436 : 1988. It conforms to BS:476 Part-7(1987) & 5(1968) and water vapor transmission conforms to BS: 4370 Part-2(1972). **Conforms to "Class O"**.

Thermal insulation material for Pipe insulation shall be Isoloyd Nil flame Polyisocyanurate Foam (PIR) Pipe section (Also available Shiplap Pipe section) with or without aluminum foil lamination, which acts as ready-made vapor barrier, of density 32 ± 2 kg/m³ and 'K' value shall not exceed 0.020 Kcal/m.hr°C (0.023 W/mK) at mean temperature of 10°C conforming to IS:12436 : 1988. It conforms to BS:476 Part-7(1987) & 5(1968) and water vapor transmission conforms to BS: 4370 Part-2(1972). **Conforms to "Class O"**.

OR

For Pipe Insulation only

Polyurethane Foam Insulation Rigid Pipe section (CFC Free)

Super foam Polyurethane Foam Pipe section (Also available Shiplap Pipe section), machine cut from buns and ready to use with or without aluminum foil lamination, which acts as ready-made vapor barrier, of density 36 ± 2 kg/m³ and 'K' value shall not exceed 0.020 Kcal/m.hr°C (0.023 W/mK) at mean temperature of 10°C conforming to IS : 12436-1988 and BS: 476 Part-5(1968) and water vapor transmission conforms to BS:4370 Part-2(1972)

Insulation material for Duct Acoustic Lining shall be elastomeric Nitrile rubber.

OR

The acoustic lining shall consist of 25mm rigid slabs of Rockloyd Resin Bonded non-combustible Grade Rockwool of density of 64 kg/m³. Then it shall be covered by 26G perforated aluminum sheets having min. 15% perforation.

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 thermal conductivity values, density, water vapor permeability and fire properties. 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, vapor proof adhesive strictly as per manufacturer's recommendations.

Ducting insulation thickness shall be as per table below.

Elastomeric Nitrile Rubber with factory laminated black glass cloth

| Ducting position | Thickness for non-coastal places | Thickness for coastal places |
|--------------------------|----------------------------------|--------------------------------|
| SA duct in RA path | 13mm | 16mm |
| Ducted return air system | SA duct: 19mm RA duct: 9mm | SA duct: 32mm RA duct: 13mm |
| Both SA& RA exposed | Both 25mm | Both 32mm |

Cross linked Polyethylene foam with factory laminated black glass cloth/ Aluminum foil facing

| Ducting position | Thickness for non-coastal places | Thickness for coastal places |
|--------------------------|----------------------------------|--------------------------------|
| SA duct in RA path | 13mm | 19mm |
| Ducted return air system | SA duct: 19mm RA duct: 13mm | SA duct: 25mm RA duct: 19mm |
| Both SA& RA exposed | Both 25mm | Both 25mm |

Rigid Polyisocyanurate Foam Insulation(CFC Free)

| Ducting position | Thk. For non-coastal places | Thk. For coastal places |
|--------------------------|------------------------------|------------------------------|
| SA duct in RA path | 25mm | 30mm |
| Ducted return air system | SA duct:30mm RA duct:25mm | SA duct:40mm RA duct:30mm |
| Both SA & RA exposed | Both 40mm | Both 40mm |

Resin Bonded Rockwool Insulation

| Ducting position | Thk. For non-coastal places | Thk. For coastal places |
|--------------------------|------------------------------|------------------------------|
| SA duct in RA path | 25mm | 40mm |
| Ducted return air system | SA duct:40mm RA duct:25mm | SA duct:50mm RA duct:40mm |
| Both SA & RA exposed | Both 65mm | Both 65mm |

3. DUCT ACOUSTIC LINING

Insulation material for Duct Acoustic Lining shall be elastomeric Nitrile rubber.

Material shall be engineered Nitrile Rubber open cell foam. The material should be fiber free. The density of the same shall be within 140-180 Kg/m³. It should have antimicrobial product protection, and should pass Fungi Resistance as per ASTM G 21 and Bacterial Resistance as per ASTM E 2180. The material should have a thermal conductivity not exceeding 0.047 W/m.K @ 20 Deg. C . The material should withstand maximum surface temperature of +85°C and minimum surface temperature of -20°C. The material should conform to Class 1 rating for surface spread of Flame in accordance to BS 476 Part 7 & UL 94 (HBF, HF 1 & HF 2) in accordance to UL 94, 1996. 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 as specified for the individual application. The insulation should be installed as per manufacturer's recommendation. *The adhesive shall be specially formulated for the Duct insulation application and supplied by insulation manufacturer. The adhesive shall be Solvent based rubber insulation adhesive, free from benzene.* Ducts so identified and marked on Drawings and included in Schedule of Quantities shall be provided with acoustic lining of thermal insulation material for a distance of minimum 5 meters (or 30% of the duct length whichever is more).

Installation Procedure

The inside surface for the ducts shall be covered with adhesive recommended by the manufacturer. Cut Foamed sheets into required sizes apply adhesive on the foam and stick it to the duct surface

OR

Insulation material for Duct Acoustic Lining shall be resin bonded Rockwool

Material shall be **Rockloyd Resin Bonded non-combustible Grade Rockwool (tested to BS: 476 Parts 4,5,6,7) of density 48 kg/m³** conforming to IS : 8183-1993. Material shall be in the form of slabs of uniform thickness and laminated with aluminum foil. The 'K' value at 10°C shall not exceed 0.029 Kcal/m.hr°C (0.030 W/mK). The Product shall have temperature range of -10°C to +750°C. Thickness of material shall be as specified for the individual application.

Ducts so identified and marked on drawings and included in schedule of quantities shall be provided with acoustic lining of thermal insulation material for a distance of minimum 5 meters as follows:

The inside surface for the ducts shall be covered with adhesive, and provided with 22 gauge GI Channels 25X25mm screwed back to back and fixed on the inside of the duct, spaced not more than 60 cm Centre to form a frame work of 60X 60 cms². Cut panels 60X60 cms or 60X75cms of resin bonded Rockwool 25mm thick shall be fitted in the squares or 60X75cms rectangles.

These insulation panels shall be fixed to the sheet metal with cold setting adhesives compound. The inner most surface shall be covered with fiberglass tissue and 28gauge perforated aluminum sheet having at least 15 percent perforations. The aluminum sheet shall be screwed to GI channels using cup washer and neatly finished to give true inside surface.

4. DUCT INSULATION

External thermal insulation shall be provided as follows:

The thickness of nitrile rubber/cross linked polyethylene foam (XLPE) and shall be as shown on drawing 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 elastomeric rubber/XLPE and sheets to size with sufficient allowance in dimension. Cutting of nitrile rubber/XLPE and sheets shall be done with adjustable blade to make 90° cut in thickness of nitrile rubber/XLPE sheet. 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. A thin film of adhesive shall be applied on the back of the insulating material sheet and then on to the metal surface. When adhesive is tack dry, insulating material sheet shall be placed in position and pressed firmly to achieve a good bond. All longitudinal and transverse joints shall be sealed by providing 6 mm thick 50 mm wide nitrile rubber tape/3mm thick 50mm wide XLPE tape. The adhesive shall be strictly as recommended by the manufacturer.

OR

External thermal Insulation shall be provided as follows;

The thickness of Resin Bonded Rockwool / Polyisocynurate foam(PIR) insulation slab with Al. foil lamination shall be as shown in drawing or identified in the schedule of quantity, following procedure shall be adhered to:

Duct Surface shall be cleaned to remove all the grease, oil, dirt prior to carrying out insulation work. Material shall be fitted under compression and no stretching of material shall be permitted.

Fix self-adhesive GI Pins / fasteners of appropriate length at regular interval of 300mm on top, 180mm on sides and at 150mm interval at the bottom. A layer of suitable adhesive shall be applied on the metal surface. When adhesive is tack dry, insulating material shall be placed in position and pressed firmly to achieve a good bond and secured to ducts by means of metal staples or insulation stick pins. These pins shall be applied on 600mm centers on all duct surfaces.

All longitudinal and transverse joints shall be sealed by providing 75mm wide reinforced Aluminum tape (duct tape). PUF battens shall be provided at duct locations to ensure insulation does not compress at duct support locations. The entire duct shall clad with suitable thick aluminum sheets.

| | RW | PIR |
|---------------------------------------|--------------|--------------|
| AC duct in conditioned space | 25 mm | 25 mm |
| AC duct in unconditioned space | 50 mm | 30 mm |
| AC duct with treated fresh air | 50 mm | 30 mm |

5. PIPING INSULATION

All chilled water, refrigerant, and condensate drain piping shall be insulated in the manner specified herein. Before applying insulation, all pipes shall be brushed and cleaned. All MS pipes shall be provided with a coat of zinc chromate primer. Thermal insulation shall be applied as follows or as specified in drawings or schedule of quantity:

Elastomeric Nitrile Rubber with factory laminated black glass cloth

| Pipe nominal bore | Thickness for non-coastal places | Thickness for coastal places |
|--------------------------|---|-------------------------------------|
| 15mm – 40mm | 25mm | 32mm |
| 50mm – 150mm | 25mm | 38mm |
| 200mm – 300mm | 32mm | 44mm |
| 350mm – 600mm | 32mm | 44mm |

Cross linked Polyethylene foam with factory laminated black glass cloth/ Aluminum foil facing

| Pipe nominal bore | Thickness for non-coastal places | Thickness for coastal places |
|--------------------------|---|-------------------------------------|
| 15mm – 40mm | 20mm | 25mm |
| 50mm – 80mm | 25mm | 32mm |
| 100mm – 300mm | 30mm | 38mm |
| 350mm – 600mm | 40mm | 45mm |

Insulating material in tube form 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 cut out in correct dimension using correct tools. Scissors or Hacksaw-blade shall not be allowed. All longitudinal and transverse joints shall be sealed as per manufacturer recommendations. All longitudinal and transverse joints shall be sealed by providing 6 mm thick, 50 mm wide nitrile rubber tape or 3mm thick, 50mm wide XLPE tape. 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. Manufacturer's installation manual shall be submitted and followed for full compliance. All insulation work shall be carried out by skilled workmen specially trained 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 color 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.

OR

Pipe section/In-situ PIR/PUF

| Pipe Nominal Bore | Thickness for Non Coastal places | Thickness for Coastal places |
|-------------------|----------------------------------|------------------------------|
| 15mm to 25mm | 40mm | 50 mm |
| 32mm to 80mm | 50 mm | 60 mm |
| 100mm to 400mm | 60 mm | 65 mm |
| Above 400mm | 70 mm | 70 mm |

The above thicknesses are designed for heat ingress of 5.5W/m² at 10°C operating temperature of chilled water and to prevent surface condensation at 35°C ambient temperature, 85% relative humidity

Remolded pipe sections shall be placed over the pipes, the longitudinal and transversal joints of these pipe sections shall be sealed with the adhesive compound. The insulation shall be continuous over the entire run of piping, fittings and valves.

If owner allows option for **Cast in-Situ foaming the same can be suggested** with correct application procedure. Super foam Polyurethane Foam insulation (PUF) applied by Cast in-situ foaming method at a density of 40±2 kg/m³. The system shall be in accordance with IS: 13205.

Method of application

Surface to be insulated shall be cleaned properly & if the surface is painted ensure that there is no damage to protective layer due to cleaning. Pre Formed Pipe Sections of required thickness should be fixed with adhesive as specified by manufacturer. The joints of pre Formed Sections shall be sealed with the specified sealant as per directions of manufacturer. The insulation shall be secured with bands / Tape at 300mm Centre to Centre distance. Vapor Barrier mastic, in two coats, with a fabric shall be applied for reinforcement in between. Provide and fix external protection, if any (such as metal cladding / Weather Barrier) over the above taking care to see that the Vapor Barrier layer is neither disturbed nor damaged. All longitudinal and transverse joints in the outer cladding shall have a minimum overlap of 50mm duly beaded and grooved and shall be sealed suitable.

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

PRE-INSULATED PIPES: Polyurethane foam Insulation

All buried chilled water pipes and condensate drain pipes shall be reinsulated type.

Buried chilled water pipes and condensate drain pipes are shown on layout drawings.

The system shall be non-corrosive, non-metallic, structurally strong completely water proof and entirely resistance to attack by salts, water and all ground chemicals normally encountered. The system manufacturer shall have fabricated systems of the composition defined here for at least five years.

All straight sections fittings, anchors end seals and other accessories shall be factory prefabricated to the project dimensions. The same may be allowed at site if OWNER permits. Pipe movement due to thermal expansion shall be accommodated with expansion loops or elbows. PVC warning tape shall be provided 300 mm above the buried throughout the length of the pipe (By others).

MATERIAL

Pre-insulated, jacketed pipe work shall conform to the following specifications.

The **core pipe shall be MS, ERW heavy duty** class to comply with thickness as mentioned in BOQ. All pipes shall be with beveled ends for welded joint.

The **insulation shall be Lloyd foam rigid cellular polyurethane foam, injected** between the core pipe and the outer casing/jacket, having a density of 40kg/m³ (2.5 lbs/ft³) nominal and thermal conductivity coefficient of 0.021W/m²K maximum at a mean temperature of 24°C (75°F). The insulation shall meet IS 12436 specifications with typical operating temperature between -30°C to +100°C.

The outer casing/jacket shall be made of **extruded high-density Polyethylene (HDPE) pipe** having a density of 900 to 960 kg/m³. HDPE wall thickness shall be 4mm thick for 60.3 mm dia and above. For small bore pipes (below 60.3mm) available HDPE pipes shall be used, where thickness can be lower than 4mm as per standard for HDPE pipes. Material shall be UV resistant.

Pre-insulation process shall be by high pressure foaming machine. Due care shall be taken to avoid air gaps. All ends of straight pipes and fittings shall be sealed with polyolefin end seal, applied to the exposed ends of the insulation for protection against moisture ingress.

The field joint insulation shall consist of polyurethane foam chemical poured into a 4mm thick HDPE sheet roll-up around the joint. Contractor shall provide methodology for approval of consultant before proceeding with work at site.

6. MECHANICAL AND UV PROTECTION OVER INSULATION

To provide mechanical strength and protection from damage all pipe / duct insulated with nitrile rubber as indicated in BOQ shall be covered with fiber glass fabric of 7 mil minimum thickness. Insulated pipes & ducts exposed to UV rays shall be covered with fiber glass fabric. Over the fabric one coat of fire proof epoxy or acrylic compound shall be applied. The coat shall be allowed to cure to nonstick state. Subsequently second coat of compound shall be applied to give a tough and smooth finish to the insulated surface.

Closed cell cross linked polyethylene foam shall be provided with factory laminated aluminum film foil for indoor applications or with factory laminated fiber glass cloth facing for external (exposed) applications. Over the fabric one coat of fire proof epoxy or 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 give a tough and smooth finish to the insulated surface.

OR

Rockwool/PUF/PIR insulation shall be provided with factory laminated Aluminum foil for both pipe and duct insulation.

To provide extra mechanical strength & protection from damage all pipe insulated with Rockwool/PUF/PIR as indicated in BOQ shall be covered with Aluminum roll jacketing manufactured from alloys 3105 and 3003 conforming to ASTM B-209 designation, half hard temper (H-14) up to 36" outer diameter 0.5mm thick aluminum shall be used and 0.8mm (above 36" dia) shall be used. AL cladding shall be with PolySurlyn coated moisture barrier.

Alternatively color coated Galvanized steel cladding of 0.5mm thick 270gsm as per IS: 277 (with color selected by the clients) may be provided.

7. 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.

8. SHELL INSULATION

The chiller shells shall be factory insulated in accordance with the manufacturer's standards.

9. COLD WATER AND EXPANSION TANK INSULATION

Cold water tank and chilled water expansion tank shall be insulated as per manufacturer's standard.

10. ACOUSTIC LINING OF MECHANICAL ROOMS

Two walls and ceiling of air conditioning plant room and air handling unit rooms may be provided with acoustic lining approved material as per Schedule of Quantities and as shown on the Drawings. Installation procedure shall be as per manufacturer's standard. Acoustic lining of walls shall be terminated approximately 15 cm above the finished floor to prevent damage to insulation due to accidental water-logging in plant/AHU rooms.

OR

Two walls and ceiling of air conditioning plant room and air handling unit rooms may be provided with acoustic lining of **lightly resin bonded Rockwool slab** as per Schedule of Quantities and as shown on the Drawings. The surface shall be cleaned and frame work of 22 gauge GI fabricated channels 25 mm x 50mm screwed back to back at 60 cm centers shall be provided vertically and horizontally so that 60X 60 cm square are formed. The gaps between frames shall be filled with 50mm thick about 60cm X 60cm cut panels of lightly resin bonded Rock wool slabs. The entire surface shall then be covered with fiber glass tissue and 26 gage perforated aluminum sheet, 60cm or 120 cm wide having at least 15 percent perforations, fixed with sheet metal screws. Over-lapping of sheets shall be covered with Aluminum beading. Acoustic lining of walls shall be terminated approximately 15cm above the finished floor to prevent damage to insulation due to accidental water-logging in plant / AHU rooms. The material shall be in accordance with IS 8183:1993

11. OVERDECK INSULATION

Over deck insulation shall be done with 75 mm thick extruded polystyrene of density 45-48 kg/cm³ & thermal conductivity of 0.21 Btu in / ft²hr°F (at 24°C as per ASTM C – 518). Minimum compressive strength as per ASTM D-2842 shall be 570 kPa water absorption as per ASTM D-2842 shall not be more than 1%.

OR

Over deck insulation shall be done closed cell Rigid Cellular Polyurethane foam of suitable thickness of with density 36±2 kg/cm³ & thermal conductivity of 0.21 W/mK (0.1456 Btu in/ ft² hr°F) at 10°C mean temperature Minimum compressive strength shall be 172KN/m² (min).

Method of Application

- (a) Clean RCC slab and make it free from dust and other laitance matter.
- (b) Lay cement based water proofing on roof with a minimum slope of 1:100 and average thickness of 110 mm using brickbats of appropriate size and shape suitable to achieve the required slope laid over 15 mm thick waterproof cement mortar 1:4 and finished with 20 mm thick waterproof plaster with cement mortar 1:4 and making false squares of 300 mm size including rounding off the junction of roof and parapet walls for a height of 300 mm with brickbats and 20 mm thick waterproof plaster and conducting necessary leakage / dampers tests, etc.
- (c) Lay 65 mm thick extruded polystyrene boards/**50mm thick Polyurethane foam slab** over prepared surface fixing with adhesive. Adhesive shall be strictly as per recommendations from manufacturer.

(d) Lay 80 gsm geotextile fabric or **400G Polythene sheet** over insulation board

(e) Lay 40 x 40 x 4 cm precast paver blocks.

(Note : If contractor is awarded work of waterproofing + over deck insulation, follow all steps from (a) to (e). if contractor is awarded work of only over deck insulation follow step (c) and (d). Rest will be done by Civil Contractor).

OR

OVERDECK INSULATION

Lloyd foam CFC free Closed Cell Spray Polyurethane Foam insulation of density 40-45kg/m³ and thickness 40 mm. Lloyd foam conforms to IS: 12432 Part-3 and having thermal conductivity value 0.023 W/mK at 10 deg.C mean temperature. Lloyd foam has min. 92% closed cell content and negligible water absorption 0.2 kg/m³ (7 days).Lloyd foam is sprayed with the help of two components Gusmer machines, which are capable of maintaining the mix ratio at $\pm 2\%$ accuracy minimizing wastage

APPLICATION SPECIFICATIONS

1. Roof slab should be totally dried and free from all protrusions and depressions and should have proper sloped for free flow of water.
2. Cleaning the surface properly with wire brushes manually.
3. Providing and applying a coat of Polyurethane primer at entire roof surface @ 6-8 Sqm/Ltr.
4. Providing and applying 40mm thick closed cell CFC Free Lloyd foam sprayed Polyurethane Foam with Graco / Gusmer machine.– Lloyd foam Over deck insulation conforming to IS : 12432 part III:2002, Density of Foam shall be 40-45kg/m³. The sprayed foam adheres instantly to the roof surface.
5. Providing and laying 400g polythene sheet over the fixed PUF Spray, for the protection and as separation layer.
6. Providing and laying in slope gradient min.40mm thick PCC(1:2:4)in chequered 2.5mtr x2.5mtr panels, reinforced with welded mesh of 75mm x 75mm x1.5mm embedded in between over the Polythene sheet
7. Sealing all joints between panels with polymerized mastic.
8. Providing suitable waterproofing treatment and final top finish as per specs or engineer in-charge.

12. UNDERDECK INSULATION

Under deck insulation shall be 50mm thick TF Quality expanded polystyrene (32 Kg/m³) or 30mm thick phenotherm. Under deck surface of ceiling shall be cleaned and made dirt free. Insulation panels shall be pasted on this surface with black CPRX compound. 28g 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 Magnetic Bearinged with galvanized Magnetic Bearings to avoid rusting.

OR

IsolloydNilflame Rigid CFC free PIR (Polyisocyanurate) foam insulation of 30mm thick and density of 32+2 kg/m³ having thermal conductivity value of 0.021 W/mK at 10 °C mean temp.

The slabs will have one side aluminum foil lamination it is available in slab form 1 mtr.X ½ mtr. Fire Properties **Conforms to Class-O**. Under deck surface of ceiling shall be cleaned and made dirt free. Insulation panels shall be pasted on this surface with black CPRX compound and further holding it with screw.

OR

Resin Bonded Non-combustible Grade Rockwool

Under deck insulation with Resin Bonded Rockloyd Rockwool conforming to IS: 8183 and density 48 kg/ m³, 50 mm thick, wrapped in 200 G Virgin Polythene bags fixed to ceiling with metallic cleats (50x50x3 mm) @ 60 cm and wire mesh of 12.5mm x 24gauge wire mesh, for top most ceiling of building. The 'K' value at 10°C shall not exceed 0.029 Kcal/m.hr°C (0.030 W/mK). The Product shall have temperature range of -10°C to +750°C

13. SOUND ATTENUATORS

Attenuators shall be installed in ducts in accordance with requirements of drawings and as included in Schedule of 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 |
| iv | Guest floor corridors | 30-35 |
| 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 | 30-35 |
| x | Office Corridor | 35-40 |

- b. Attenuators shall be of steel construction with casings out of minimum 22 G galvanized steel. Acoustic fill shall be inert, non-hygroscopic, vermin proof, fiber glass of required density adequately protected against corrosion and covered with 26 gage perforated aluminum sheet. Attenuators shall be supplied complete with flanges.

- c. Acoustic performance of the attenuators (net insertion 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 | 34 | 23 | 14 |

- d. The pressure drop values of the silencers shall be 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 ACMA test methods/BS 4718 and insertion loss and self-generated noise for each octave band and pressure drop shall be stated in the schedule.

14. MEASUREMENT OF INSULATION

Unless otherwise specified measurement for duct and pipe insulation for the project shall be on the basis of Centre line measurements described herewith

- a. Pipe Insulation shall be measured in units of length along the Centre line of the installed pipe, strictly on the same basis as the piping measurements described earlier. The linear measurements shall be taken before the application of the insulation. It may be noted that for piping measurement, all valves, orifice plates and strainers are separately measurable by their number and size. It is to be clearly understood that for the insulation measurements, all these accessories including cladding, valves, orifice plates and strainers shall be considered strictly by linear measurements along the Centre line of pipes and no special rate shall be applicable for insulation of any accessories, fixtures or fittings whatsoever.
- b. Duct Insulation and Acoustic Lining shall be measured on the basis of surface area along the Centre line of insulation thickness. Thus the surface area of externally thermally insulated or acoustically lined be based on the perimeter comprising Centre line (of thickness of insulation) width and depth of the cross section of insulated or lined duct, multiplied by the Centre-line length including tapered pieces, bends, tees, branches, etc. as measured for bare ducting.

SECTION XV : AUTOMATIC CONTROLS AND INSTRUMENTS

1 SCOPE

The scope of this section comprises the supply, erection, testing and commissioning of automatic controls and instruments conforming to these Specifications and in accordance with the requirements of Drawings and Schedule of Quantities.

2 TYPE

All automatic controls shall be electric controls as described in the various sections of these Specifications. All instruments shall be as described in the various sections of these Specifications.

3 AUTOMATIC CONTROLS

Automatic controls required for various types of machines have been described in the various sections of these specifications and shown on the Drawings. The individual safety controls and selected automatic controls, may be installed within the machines by the manufacturers before shipment. However, the following automatic controls, if not already installed on the machines, may be installed at site by the contractor, as indicated in Schedule of Quantities.

- a) Two way modulating control valve for each air handling units shall be provided in chilled water line at each air handling unit as shown on the Drawings and included in Schedule of Quantities. The valve shall be balanced, high rangeability, globe type of cast iron construction, of PN 16 rating with flanged connections. The valve shall have a minimum stroke of 15 mm and rangeability of 300. The valve actuator shall be electronic, motorized, modulating type with linear stroke, operating on 24Vac and 0-10 Vdc or 4-20 mA control signal. The actuator shall have provision for 0-10v dc position feedback signal and manual operation mode also. It shall be possible to operate the valve manually and the actuator shall switch back to auto mode when the power is restored. The valve actuator housing shall have IP 54 protection. The actuator should be suitable for a valve close-up pressure of 1.5 times the pump head or a minimum of 4 bars. Each valve shall be controlled by a space temperature controller with a provision to limit the flow through the control valve based on temperature difference across the coil
- b) Two way or Three -way diverting Valve for each fan coil unit shall be provided in chilled water lines at each fan coil unit as shown on Drawings and included in Schedule of Quantities. The valve shall be actuated by space thermostat. Constant space conditions shall be maintained by allowing all of chilled water to either pass through the coil or bypass the coil and mix with the chilled water return. The valve shall be provided with spring return function so that it reverts to fully bypass position when fan is shut off.

Valve shall be similar to Honeywell two position diverting valves 15 cm (1/2 inch) diameter with flare connection. Valve shall be selected for water flow rate of 5-6 USGPM. Pressure drop across the valve shall not exceed 2 psi. Valve shall have the facility to replace motor & actuator without removing the valve body.

- c) Flow Switch shall be provided in condensing water outlet and chilled water outlet at each water chilling machine, and at each water-cooled condensing unit for refrigeration system in cold stores, as shown on Drawings and included in Schedule of Quantities. Flow switch shall prevent the compressor from starting unless the cooling water flow is established in condensing water lines, and chilled water flow is established in chilled water lines.
- d) Thermostat shall be electric, fixed differential cooling / heating type as specified herein, with sensing element located in the return air stream. All thermostats shall be supplied with the standard mounting boxes, as recommend by the manufacturer. The profiles, mounting arrangement and exact location of thermostats shall be approved at site. Requirement of thermostats shall be as shown on Drawings and included in Schedule of Quantities.

- i. Proportional control thermostats for air conditioning application for actuating the two way or three way modulating valve at each air handling unit, as shown on Drawings and included in Schedule of Quantities. Thermostat shall be similar to Honeywell model T921B/T92A or equivalent, line voltage cooling thermostat. Range shall be 56-84 degree F, differential shall be 3 degree F.
- ii. Proportionate type thermostat for air conditioning applications for modulation of two way or three-way diverting valve at each fan coil unit as shown on Drawings and included in Schedule of Quantities.

Thermostat shall be similar to Honeywell model T694A or T4039 and RCC20 or RDF 300 Siemens, V30 CIAT, RTR72XX Eberle or equivalent cooling thermostat, for range 56-84 degree F, differential 3 degree F, with OFF-HI-MED-LO fan switch, temperature adjustment NORMAL-COOL setting. Switching off must break fan circuit.

- iii. Snap acting fixed differential heating thermostat for electric reheat applications for putting on/off power supply to electric reheat coil in air handling unit as shown on Drawings and included in Schedule of Quantities. Thermostat shall be similar to Honeywell; model T451A, two stage thermostat.
- iv. Safety thermostat for electric reheat application for cutting off power supply to tubular heaters in case air flow across tubular heater is not established. Thermostat shall be similar to Varma Trafag model MS 95R.
- e) Humidistat may be provided with air handling unit for areas which require constant indoor humidity or humidity control with reheat, as shown on Drawings and included in Schedule of Quantities. One humidistat shall activate the reheat coils in case the space humidity rises beyond the preset limit, another humidistat shall energize the humidifier when the humidity falls below the preset limit. These humidistats shall also de-energize these devices when the desired humidity is reached.

Humidistat shall be snap acting or modulating type as per the requirement, 20-80 percent relative humidity range with differential of 5 percent. Humidistat shall have removable knob to prevent tempering of set point.

- f) Airstat and Safety thermostat may be provided as shown on Drawings and included in Schedule of Quantities, within air handling units containing electric heating or reheat coils to prevent heaters from energizing unless the air flow is established.

4 INSTRUMENTS

Instruments required for different types of machines have been described in the various sections of these Specifications and shown on the Drawings. Following instruments may be provided as per the requirements indicated in the Schedule of Quantities.

- a) Thermometers: shall be dial type 100 mm dia or V form industrial type. Body shall be aluminum alloy, anodized gold-coloured surface. The casing shall be adjustable sideways for reading from the front. The glass capillary shall be triangular in shape with blue mercury filled in glass for better visibility. Scale of reading shall be of the range 0°C to 60°C & +32°F to 150°F. Graduation of scale shall be 1° in both readings. Range of scales shall be 30-120 degree F (0-50 degree C) for air conditioning applications of cooling only. Quality has been included in Schedule of Quantities.

Thermometer shall be suitable for 15 mm connections. Thermometer for chilled water shall be with long stem, so that thermometer is removable without damaging the insulation. M S socket to be welded on pipes shall be provided with thermometer. Thermometers shall be installed on chilled water supply and return at each air handling unit, supply and return at each chiller and condenser as shown on the Drawings and included in Schedule of Quantities.

- b) Pressure Gages: shall be 100 mm dia & casing made out of SS 304 installed on suction header and at discharge side of each pump, in the chilled water supply and return at each air handling unit, at inlet and outlet of each chiller and condenser, as shown on the Drawings and included in Schedule of Quantities.

Suction side gage at pump suction header shall be compound gage with 100 mm dia, range 75 cm vacuum to 10 kg (30 inch vacuum to 150 psi) pressure. Discharge sides gage at pumps and at all other locations shall be 100 mm range 0-10 kg per sq. cm (0-150 psi) pressure. Gages shall be connected to the pipes by 6 mm diameter Stainless Steel Syphon tube through a ball valve, required for gage protection.

- c) Room Thermometer: shall be dial type, wall-hung temperature indicator, of appropriate range for cold stores and deep freezers, in accordance with the requirements of Drawings and Schedule of Quantities.
- d) Room RH Indicator: shall be dial type, wall hung, relative humidity indicator of appropriate range, for special areas, in accordance with the requirements of Drawings and Schedule of Quantities.
- e) Electronic Thermometer: shall be electronically operated Digital Temperature Indicator in accordance with requirement of Drawings and as included in Schedule of Quantities. The display shall be 3-5 digit Liquid Crystal Display. The thermometer shall consist of fully solid state integrated circuit. The thermometer shall have front LED 'on' indication and automatic low battery indication. The resolution shall be 1° centigrade. Thermometer shall be complete with suitable electronic sensor to accurately sense the temperature with sensor housed in suitable air-well / thermo well for air temperature / water temperature measurement. The thermometer shall be suitable for operation on 9V DC / 230V AC. The display unit shall be housed in attractive sheet metal cabinet with prominent display of conversion charts of °F & °C on front plate. Thermometer shall be complete with separable socket type interconnecting cables of 2 m length suitable for installation within a radius of 2 m of the thermo well or air sensing point.

Electronic thermometer may be installed at chilled water supply and return at selected air handling units as shown on Drawings and included in Schedule of Quantities. Range of scale shall be 30 degree F - 120 degree F (0-50 degree C) for air conditioning application.

5. TWO WAY MODULATING / PRESSURE INDEPENDENT/ BALANCING and FLOW CONTROL VALVE

The Self balancing flow control valves that are pressure independent, 2-way, modulating to accept Input signals from the control system.

Each Air Handling Unit / Fan Coil Unit shall be provided with a 2Way Pressure Independent Balancing and Control Valve integrated in a single Body. The valve should be a Globe Type. Diaphragm based delta p controller should ensure 100% valve authority & linear characteristics at all loads and all settings.

Regarding Control - Valve should be equipped with electronic modulating gear type spring return actuator which can accept either "4(0)-20 mA / 2(0)-10V DC signals. Operating voltage for actuator shall be 24V AC.

All Valve actuators should be microprocessor based with self-calibrating feature.

Valve Actuator combination should be able to give logarithmic control characteristics to achieve linear control.

Actuator shall be able to work against pump head or maximum closing pressure. Manual Override Flow Balancing should only be done in Valve, not in actuator and should not involve opening of actuator Body.

Regarding Balancing – Each Valve should have a step less adjustable maximum flow limitation as per the designed flow rate of coils. The balancing should be done only in the valve not in the actuator so that in case of actuator failure the balancing is not lost and easily accessible.

VALVE SPECIFICATIONS

| Description | For 15 to 32 mm | For 40 to 250 mm |
|----------------------------------|---|--------------------------------|
| Diff Pressure (P1-P3) | 16 To 400 kPa | 30 To 400 kPa |
| Media Temperature | -10 ° to 120 °C, to 248 °F | -10 ° to 120 °C, to 248 °F |
| Body Material | Brass (CuZn40Pb2 - CW 617N) | Grey iron EN-GJL-250(GG25) |
| Test Ports | Needle measuring nipple | Needle measuring nipple |
| Leakage acc. to standard IEC 534 | No visible leakage (at 100N) | max.0,01 - 0.05% of kv at 650N |
| Stem Seals | EPDM - CuZn40Pb2 - CW 617N | EPDM -NBR |
| Maximum Close Off Pr | 1600 kPa, | 1600 kPa, |
| Pressure rating | PN16 | PN16 |
| Control Range | Standard IEC 534 Since CV Characteristic is Linear Control Range is Infinity | |
| Control Valve Character | Valve Actuator combination should be able to give logarithmic control characteristics to achieve linear control | |

ACTUATOR SPECIFICATIONS FOR ALL SIZES

| For Valve Sizes | 15- 32mm | 40- 100mm | 125-150mm |
|-------------------|-----------------------------|--------------------------|--------------------------|
| Actuator Type | Modulating Spring return | Modulating Spring return | Modulating Spring return |
| Supply Voltage | 24Volt AC | 24Volt AC/DC | 24Volt AC |
| Frequency | 50Hz/60 Hz | 50Hz/60 Hz | 50Hz/60 Hz |
| Power Consumption | 9VA | 14 VA | 19.2VA |
| Close of Force | 300N | 450N | 2000N |
| Maximum Stroke | 5mm | 15mm | 50mm |
| Speed | 14 Seconds/mm | 15Seconds/mm | 2 or 6 Seconds/mm |
| Protection | IP54 | IP54 | IP54 |
| Body | Non Corrosive Actuator Body | | |
| Weight | 1.8Kg | 2.3Kg | 8.6 Kg |
| Safety function | Yes | Yes | Yes |

6 CALIBRATION AND TESTING

All automatic controls and instruments shall be factory calibrated and provided with necessary instructions for site calibration and testing. Various items of the same type shall be completely interchangeable and their accuracy shall be guaranteed by the manufacturer. All automatic controls and instruments shall be tested at site for accuracy and reliability before commissioning the installation.

SECTION XVI : ELECTRICAL INSTALLATION

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.

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 centers shall be CPRI approved and shall be suitable for operation on 3 phase/single phase 415/240 volts, 50 cycles' power supply system.

3 CONSTRUCTIONAL FEATURES

The Motor Control Centre (MCC) electrical panels shall be sheet steel cabinet for indoor installation, dead front, floor mounting/wall mounting type. The control panel shall be totally enclosed, completely dust and vermin proof and shall be with hinged doors with Neoprene gasket. Control panel shall be suitable for the climatic conditions as specified in Specifications. Steel sheets used in the construction of Control panel shall be 2 mm thick and shall be folded and braced as necessary to provide a rigid support for all components. Joints of any kind in sheet metal shall be seam welded, all welding, slag shall be rounded off and welding pits wiped smooth with plumber metal. The general construction shall confirm to IS 8623 – 1977 (Part-1) for factory built assembled switchgear and control gear for voltage up to and including 1100 AC Supply.

All panels and covers shall be properly fitted and square with the frame, and holes in the panel correctly positioned. Fixing screws shall enter into holes tapped into an adequate thickness of metal or provided with wing nuts. Self-threading screws shall not be used in the construction of Control panels. A base channel of 75 mm x 75 mm x 5 mm thick shall be provided at the bottom for floor mounted panels. Minimum clearance of 200 mm shall be provided between the floor of control panel and the lowest unit.

The control panel shall be of adequate size with a provision of 25% spare space to accommodate possible future breakers. Breakers shall be arranged in multi-tier. Knockout holes of appropriate size and number shall be provided in the Motor Control Centre in conformity with the location of cable/conduit connections. Removable sheet steel plates shall be provided at the top to make holes for additional cable entry at site if required.

Every cabinet shall be provided with Trifoliate or engraved metal name plates. All panels shall be provided with circuit diagram mounted on inside of door shutter protected with Hilum sheet. All live accessible connections shall be shrouded and minimum clearance between phase and earth shall be 20 mm and phase to phase shall be 25 mm.

4 WIRING SYSTEM

All L T power cabling between MCC and motors shall be carried out with 1100 volts grade PVC insulated, overall PVC sheathed aluminum conductor armored cables, and Cables shall be sized by applying proper de-rating factor. All control wiring shall be carried out by using PVC insulated copper conductor wires in conduits. Minimum size of control wiring shall be 1.5 sq. mm.

Minimum size of conductor for power wiring shall be 4 sq. mm 1100 volts grade PVC insulated copper conductor wires in conduit.

5 CIRCUIT COMPARTMENT

Each circuit breaker, contactor and relay shall be housed in a separate compartment and shall have steel sheets on top and bottom of compartment. Sheet steel hinged lockable door shall be duly interlocked with the breaker in the "ON" position. Safety interlocks shall be provided to prevent the breaker from being drawn-out when the breaker is in 'ON' position. The door shall not form an integral part of the draw-out portion of the panel. Sheet steel barriers shall be provided between the tiers in a vertical section.

6 INSTRUMENT ACCOMMODATION

Adequate space shall be provided for accommodating instruments, indicating lamps, control contactors and control MCBs. These shall be accessible for testing and maintenance without any danger of accidental contact with live parts of the circuit breaker and bus bar 'ON' lamps shall be provided on all outgoing feeders.

7 BUS BAR CONNECTIONS

Bus bar and interconnections shall be of high conductivity electrolytic copper and of rectangular cross section suitable for carrying the rated full load current and short circuit current without overheating of phase and neutral bus bar and shall be extendable on either side. Bus bar and interconnections shall be insulated with heat shrinkable sleeve and shall be color coded and shall be supported on glass fiber reinforced thermosetting plastic insulated supports at regular intervals to withstand the force arising from in case of short circuit in the system. All bus bar shall be provided in a separate chamber and all connections shall be done by bolting. Additional cross sectional area shall be added to the bus bar to compensate for the holes. All connections between bus bar and breaker shall be through solid copper strips of proper size to carry full rated current as per approved for construction shop drawing and insulated with insulating sleeves. Bus bar shall be rated for current density of 1.28 amps/mm² cross section area.

8 TEMPERATURE - RISE LIMIT

Unless otherwise specified, in the case of external surface of enclosures of bus bar trucking system 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 temperature shall be permissible for metal surface and of 15° C above ambient temperature for insulating surfaces as per IS : 8623 (Part-2) 1998.

9 CABLE COMPARTMENTS

Cable compartment of adequate size shall be provided in the control panel for easy clamping of all incoming and outgoing cables entering from the top/bottom. Adequate supports shall be provided in cable compartment to support cables as per approved for construction shop drawing.

10 AIR CIRCUIT BREAKERS (ACB)

Air Circuit Breakers shall be sheet metal enclosed flush front, draw out type and shall be provided with a trip free manual operating mechanism or as indicated in drawings and bill of quantities with mechanical "ON" "OFF" "TRIP" indications.

The ACB shall be 4 pole with modular construction, draw out, manually operated and shall be capable of providing short circuit, overload and earth fault protection through microprocessor based control unit sensing the true RMS value to ensure accurate measurement meeting the EMI/EMC requirement as per standard.

The circuit breakers shall be for continuous rating and service short Circuit Breaking capacity shall be as specified on the single line diagram and shall be equal to the short circuit withstand values.

Circuit breakers shall be designed to 'close' and 'trip' without opening the circuit breaker compartment door. The operating handle and the mechanical trip push button shall be at the front of the breakers panel and integral with the breaker. The ACB shall be provided with a door interlock. The contacts shall be of silver plated copper with a feature of contact wear inspection, indicating the life of the contacts. The ACB shall have double insulation (Class-II) with moving and fixed contacts totally enclosed for enhanced safety and inaccessibility to live parts.

11 CRADLE

The cradle shall be so designed and constructed as to permit smooth withdrawal and insertion of the breaker into it. The movements shall be free from jerks, easy to operate and shall be on steel balls/rollers and not on flat surfaces. There shall be 4 distinct and separate position of the circuit breaker on the cradle.

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.

Maintenance : Circuit breaker fully outside the panel ready for maintenance after the cubicle door is opened.

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

12 PROTECTIONS

- a) The Microprocessor based release unit shall be provided on circuit breaker for short circuit, over current and earth fault protection with adjustable settings. The release shall incorporate an 8-bit micro-computer to offer accurate and versatile protection with complete flexibility and shall offer complete over current protection to the electrical system in the following four zones:

- Overload or long time protection.
- Short circuit or short time protection with intentional delay.
- Instantaneous protection with no intentional delay.
- Ground fault protection.
- True RMS sensing.

The release shall sample the current at the rate of 16 times per cycle to monitor the actual load current waveform flowing in the system and shall monitor the true RMS value of the load current. It shall take into account the effect of harmonics also.

- b) Thermal Memory

When the breaker shall reclose after tripping on overload, then the thermal stresses caused by the overload if not dissipated completely, shall get stored in the memory of the release and this thermal memory shall ensure reduced tripping time in case of subsequent overloads. Realistic Hot/Cold curves shall take 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. Available pick-up and time delay settings shall have flexibility for over two million different I-t characteristics to suit different applications.

- d) Trip Indication

Electromechanical fault status indicators shall be provided to display the type of fault that caused a trip, without any auxiliary supply or battery, resulting in faster fault diagnosis and reduced system down time.

- e) **Test Facility**
Test facility to test the operation of the release in different protection zones by simulating CT inputs externally through a testing kit.
- f) **Self-powered**
The release shall draw its power from the main breaker CTs and shall require no external power supply for its operation.
- g) **Tripping of the breaker**
The release shall trip the breaker through a flux shift device which shall directly act on the breaker trip rod.
- h) **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 minimizes the damage to the system.
- i) **The setting range of release shall be as follows:**

| Type of Protection | SETTING RANGE OF RELEASE | |
|--------------------|--|---|
| | PICK-UP CURRENT | TIME DELAY |
| Long Time | 0.5 to 1.0 times I_n (I_r) Steps : 0.50, 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 | 0.2 to 30 sec at 6 I_r Steps : 0.2, 0.5, 1.5, 2, 3.5, 6, 12, 17 and 30 secs Tolerance : Corresponding to $\pm 10\%$ of current. |
| Short Time | 2 to 10 times I_r Steps : 2,3,4,5,6,7,8,9 & 10 Tolerance : $\pm 15\%$ | 20 ms to 600 ms Steps : 20, 60, 100, 160, 200, 260, 300, 400, 500 and 600 ms Tolerance : $\pm 10\%$ or 20 ms whichever is higher |
| Instantaneous | 2 to 16 times I_m Steps : 2,3,4,6,8,10,12,14,16 one position as infinity. Tolerance : $\pm 15\%$ | |
| Ground Fault | 0.2 to 1 time I_m Steps : 0.2,0.3,0.4,0.5,0.6, 0.7, 0.8, 0.9 & 1.0 Tolerance : $\pm 15\%$ | 100 ms to 400 ms Steps : 100,200,300,400 ms & Infinity Tolerance : $\pm 10\%$ or 20 ms whichever is higher. |

Settings shall be by rotary switches having red knob for pick-up currents and blue knobs for time delays.

Factory Settings:

The release shall be set at the following values at the time of shipping :

LTP=0.5, LTD=2s, STP=9, STD=100 ms, IP=Infi, GFP=0.3, GFD=100 ms, Memory=OFF

- I. Under voltage relay for voltage is less than 90% of the rated voltage (415 V) shall be provided in the incomer breaker only.
 - II. Over voltage relay for voltage more than 110% of the rated voltage (415 V) shall be provided in the incomer breaker only.
- j) Minimum 6 NO and 6 NC auxiliary contacts shall be provided on each breaker. The contacts shall be rated 5 amps.
- k) Rated insulation voltage shall be 1000 volts AC.

The auxiliary contacts blocks shall be so located as to be accessible from the front. The auxiliary contacts in the trip circuits shall close before the main contacts have closed. All other contacts shall close simultaneously with the main contacts. The auxiliary contacts in the trip circuits shall open after the main contacts open.

All current carrying parts shall be silver plated and suitable arcing contacts with proper arc chutes shall be provided to protect the main contacts. The heat generated in the contacts due to tripping under fault conditions shall be very nominal. All air circuit breakers shall be labeled.

13 SAFETY FEATURES

- I. The safety shutter shall prevent inadvertent contact with isolating contacts when breaker is withdrawn from the Cradle.
- II. It shall not be possible to interchange two circuit breakers of two different thermal ratings.
- III. There shall be provision 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. Arc Chute covers wherever necessary shall be provided.
- V. 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 current transformers.
- VI. 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.

14 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 as specified in BOQ. MCCB shall comply 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. MCCB shall comprise of Quick Make -break switching mechanism, arc extinguishing device and the tripping unit shall 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 MCCB shall be as specified in the schedule of quantities. 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 with ROM should meet IP54 degree of protection.

a) Current Limiting & Coordination

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

Protection Functions

- MCCBs with ratings up to 200 A shall be equipped with Thermal-magnetic (thermal for overload and magnetic for short-circuit protection) trip units
- Microprocessor MCCBs with ratings 250A and above shall be equipped with microprocessor based trip 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 units shall comply with appendix F of IEC 60947-2 standard (measurement of rms current values, electromagnetic compatibility, etc.)
- Protection settings shall apply to all poles of circuit breaker.
- All Microprocessor components shall withstand temperatures up to 125 °C

b) Testing

- i) Original test certificate of the MCCB as per IEC 60947-1 &2 or IS13947 shall be furnished.
- i. Pre-commissioning tests on the switch board panel incorporating the MCCB shall be done as per standard specifications.

c) Interlocking

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

- i) Handle interlock to prevent unnecessary manipulations of the breaker.
- ii) Door interlock to prevent the door being opened when the breaker is in ON position.
- ii. 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 shall be capable of defined variable overload adjustment. All MCCBs rated 200 Amps and above shall have adjustable over load & short circuit pick-up both in Thermal magnetic and Microprocessor Trip Units.
 - All MCCB with microprocessor based release unit, the protection shall be adjustable Overload, Short circuit and earth fault protection with time delay.

The trip command shall override all other commands.

15 MINIATURE CIRCUIT BREAKER (MCB)

Miniature Circuit Breaker shall comply with relevant BIS Codes and shall be quick make and break type for 230/415 VAC 50 Hz application with magnetic thermal release for over current and short circuit protection. The breaking capacity shall not 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 MCB shall have the minimum power loss (Watts) per pole defined as per the IS/IEC and the manufacturer shall publish the values.

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

16 PAINTING

All sheet steel work shall undergo a process of degreasing, pickling in acid, cold rinsing, phosphating, passivating (seven tank processing) and then painted with electrostatic paint (Powder coating). The shade of color of panel inside/outside shall be as per relevant BIS code.

17 LABELS

Engraved PVC labels shall be provided on all incoming and outgoing feeder. Circuit diagram showing the arrangements of the circuit inside the control panel shall be pasted on inside of the panel door and covered with transparent plastic sheet.

18 METERS

- i. All voltmeters and indicating lamps shall be through MCB's.
- ii. Meters and indicating instruments shall be plug type.
- iii. All CT's connection for meters shall be through Test Terminal Block (TTB).
- iv. CT ratio and burdens shall be as specified on the Single line diagram.

19 CURRENT TRANSFORMERS

Current transformers shall be provided for Control panels carrying current in excess of 60 amps. All phase shall be provided with current transformers of suitable VA burden with 5 amps secondary's for operation of associated metering.

The CTs shall conform 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. Secondary terminals of CTs shall be brought out suitable to a terminal block which shall be easily accessible for testing and terminal connections. The protection CTs shall be of accuracy class 5P10 and measurement CTs shall be of accuracy class I.

20 SELECTOR SWITCH

Where called for, selector switches of rated capacity shall be provided in control panels, to give the choice of operating equipment in selective mode.

21 STARTERS

Each motor shall be provided with a starter of suitable rating. Starters shall be in accordance with relevant IS Codes. All Star Delta and ATS Starters shall be fully automatic.

22 CONTACTOR

Contactor shall be built into a high strength thermoplastic body and shall be provided with an arc shield for quick arc extinguishing. Silver alloy tips shall be provided to ensure a high degree of reliability and endurance under continuous operation. The magnet system shall consist of laminated yoke and armature to ensure clean operation without hum or chatter. Starter's contactors shall have 3 main and 2 Nos. NO / NC auxiliary contacts and shall be air break type suitable for making and breaking contact at minimum power factor of 0.35.

For design consideration of contactors the starting current of connected motor shall be assumed to be 6 times the full load current of the motor in case of direct-on-line starters and 3 times the full load current of the motor in case of Star Delta and Reduced Voltage Starters. The insulation for contactor coils shall be of Class "E".

Coil shall be tape wound vacuum impregnated and shall be housed in a thermostatic bobbin, suitable for tropical conditions and shall withstand voltage fluctuations. Coil shall be suitable for 220/415 \pm 10% volts AC, 50 cycles AC supply.

23 THERMAL OVERLOAD RELAY

Thermal over load relay shall have built in phase failure sensitive tripping mechanism to prevent against single phasing as well as on overloading. The relay shall operate 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 of three element, positive acting ambient temperature compensated time lagged thermal over load relays with adjustable setting. Relays shall be directly connected for motors up to 35 HP capacity. C.T. operated relays shall be provided for motors above 35 HP capacity. Heater circuit contactors may not be provided with overload relays.

24 TIME DELAY RELAYS

Time delay relays shall be adjustable type with time delay adjustment from 0-180 seconds and shall have one set of auxiliary contacts for indicating lamp connection.

25 INDICATING LAMP AND METERING

All meters and indicating lamps shall be in accordance with BS 37 and BS 39. The meters shall be flush mounted type. The indicating lamp shall be of low wattage. Each MCC and control panel shall be provided with voltmeter 0-500 volts with three way and off selector switch, CT operated ammeter of suitable range with three nos. CTS of suitable ratio with three way and off selector switch, phase indicating lamps, and other indicating lamps as called for. Each phase indicating lamp shall be backed up with 5 amps fuse. Other indicating lamps shall be backed up with fuses as called for in Schedule of Quantities.

26 TOGGLE SWITCH

Toggle switches, where called for in Schedule of Quantities, shall be in conformity with relevant IS Codes and shall be of 5 amps rating.

27 PUSH BUTTON STATIONS

Push button stations shall be provided for manual starting and stopping of motors / equipment. Green and Red color push buttons shall be provided for 'Starting' and 'Stopping' operations. 'Start' or 'Stop' indicating flaps shall be provided for push buttons. Push Buttons shall be suitable for panel mounting and accessible from front without opening door, Lock lever shall be provided for 'Stop' push buttons.

The push button contacts shall be suitable for 6 amps current capacity.

28 CONDUITS

Conduits and Accessories shall conform to relevant Indian Standards. Wall thickness shall be 16 gauge up to 32 mm dia and 14 gauge above 32 mm dia conduit. Screwed G.I. conduits shall be used. Joints between conduits and accessories shall be securely made, to ensure earth continuity.

All conduit accessories shall be threaded type only. All raw metal shall be painted with bit mastic paint.

Only approved make of conduits and accessories shall be used.

Conduits shall be delivered to the site of construction in original bundles and each length of conduit shall bear the label of the manufacturer.

Maximum permissible number of 650/1100 volt grade PVC insulated wires that may be drawn into rigid nonmetallic or GI Conduits are given below:

| Size of wires Nominal Cross section Area (Sq. mm.) | Maximum number of wires within conduit size(mm) | | | | |
|--|---|----|----|----|----|
| | 20 | 25 | 32 | 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 |
| 25 | -- | -- | 2 | 4 | 6 |
| 35 | -- | -- | -- | 3 | 5 |

29 CABLES

M.V. Cables shall be PVC insulated aluminum conductor and armored cables conforming to IS Codes. Cables shall be armored and suitable for laying in trenches, ducts, and on cable trays as required. M.V. Cables shall be termite resistant. Cable glands shall be double compression glands. Control cables and indicating panel cables shall be multi core PVC insulated copper conductor and armored cables.

30 CABLE LAYING

Cable shall be laid in accordance with IS code of Practice. Cables shall be laid on 14 gage factory fabricated perforated galvanized sheet steel cable trays, and cable drops / risers shall be fixed to ladder type cable trays factory fabricated out of galvanized steel angle. Access to all cables shall be provided to allow cable withdrawal / replacement in the future. Where more than one cable is running on a cable tray, one dia spacing shall be provided between cables to minimize the loss in current carrying capacity. Cables shall be suitably supported with Galvanized saddles when run on walls / trays. When buried, they shall be laid in 350 mm wide and 750 mm deep trench and shall be covered with 250 mm thick layer of soft sifted sand & protected with bricks/tiles. Special care shall be taken to ensure that the cables are not damaged at bends. The radius of bend of the cables when installed shall not be less than 12 times the diameter of cable.

31 WIRE AND WIRE SIZES

1100 volts grade PVC insulated copper conductor wires in conduit shall be used.

For all single phase/ 3 phase wiring, 1100 volts grade PVC insulated copper conductor FRLS wires shall be used. The equipment inside plant room and AHU room shall be connected to the control panel by means of insulated copper conductor wires of adequate size in exposed conduits. Final connections to the equipment shall be through wiring enclosed in galvanized flexible conduits rigidly clamped at both ends and at regular intervals.

An isolator shall be 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 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.

The minimum size of control wiring shall be 1.5 sq. mm PVC insulated stranded soft drawn copper conductor wires drawn through conduit to be provided for connecting equipment and control panels.

Power wiring, cabling shall be of the following sizes:

- | | | |
|-------|--|---|
| i. | Up to 5 HP motors/ 5 KW heaters | 3 x 4 sq. mm copper conductor wires. |
| ii. | From 6 HP to 10 HP motors 6KW to 7.5 KW heaters | 3 x 6 sq. mm copper conductor wires |
| iii. | From 12.5 HP to 15 HP motors 2 Nos. | 3 x 6 sq. mm copper conductor wires |
| iv. | From 20 HP to 25 HP motors | 2 Nos. 3 x 10 sq. mm copper conductor wires |
| v. | From 30 HP to 35 HP motors | 2 nos. 3 x 16 sq. mm aluminum conductor armored cable. |
| vi. | From 40 HP to 50 HP motors | 2 Nos. 3 x 25 sq. mm aluminum conductor armored cable. |
| vii. | From 60 HP to 75 HP motors | 1 No. 3 x 70 sq. mm aluminum conductor armored cable. |
| viii. | 100 HP motors | 1 No. 3 x 150 sq. mm. aluminum conductor armored cable. |
| ix. | 150 HP motor | 1 No. 3 x 240 sq. mm. aluminum conductor armored cable. |
| x. | 250 HP motor | 2 Nos. 3 x 240 sq. mm.aluminium conductor armored cable. |
| xi. | 400 HP motor | 3 Nos. 3 x 240 sq. mm. aluminum conductor armored cable. |
| xii. | 600 HP motor | 3 Nos. 3 x 400 sq. mm.aluminium conductor armored cable. |

All the switches, contactors, push button stations, indicating lamps shall be distinctly marked with a small description of the service installed. The following capacity contactors and overload relays shall be provided for different capacity motors or as per manufacturer's recommendation.

| | | | CONTACTOR CURRENT CAPACITY | OVERLOAD RELAY RANGE |
|--------------------|-----------|----------------------|----------------------------------|----------------------------|
| TYPE OF STARTER | | | | |
| 5 | HP Motors | D O L | 16 amps | 6-10 amps |
| 7.5 | HP motors | D O L | 16 amps | 9-15 amps |
| 10 | HP Motors | Star Delta | 25 amps | 9-15 amps |
| 12.5 | HP Motors | Star Delta | 16 amps | 9-15 amps |
| 15 | HP Motors | Star Delta | 25 amps | 9-15 amps |
| 20 | HP Motors | Star Delta | 32 amps | 14-23 amps |
| 25 | HP Motors | Star Delta | 32 amps | 14-23 amps |
| 30 | HP Motors | Star Delta | 40 amps | 20-33 amps |
| 35 | HP Motors | Star Delta | 40 amps | 20-33 amps |
| 40 | HP Motors | Star Delta | 40 amps | 30-50 amps |
| 50 | HP Motors | Automatic Star Delta | 70 amps | 30-50 amps |
| 60 | HP Motors | Automatic Star Delta | 110 amps | 30-50 amps |
| 75 | HP Motors | Automatic Star Delta | 110 amps | 90-150 amps |
| 100 | HP Motors | Automatic Star Delta | 200 amps | CT operated relay |
| 125 | HP Motors | Automatic Star Delta | 200 amps | CT operated relay |
| 150 | HP Motors | Automatic Star Delta | 200 amps | CT operated relay |
| 150 | HP Motors | Auto Transformer | 300 amps | CT operated Relay. |
| 200 | HP Motors | Auto Transformer | 300 amps | CT operated Relay. |
| 250 | HP Motors | Auto Transformer | 400 amps | CT operated Relay. |
| 300 | HP Motors | Auto Transformer | 400 amps | CT operated Relay. |
| 400 | HP Motors | Auto Transformer | 600 amps | CT operated Relay. |
| 600 | HP Motors | Auto Transformer | 900 amps | CT operated Relay. |

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

32 EARTHING

Earthing shall be provided in accordance with IS : 3043 – 1987 and shall be copper strips /wires .The main panel shall be connected to main earthing system of the power supply. All single phase metal clad switches and control panels be earthed with minimum 3 mm diameter copper conductor wire. All 3 phase motors and equipment shall be earthed with 2 numbers distinct and independent copper wires / tapes as follows:

- i. Motor up to and including 10 HP rating. 2 Nos. 3 mm dia copper wires.
- ii. Motor 12.5 HP to 40 HP capacity 2 Nos. 4 mm dia copper wires.
- iii. Motor 50 to 75 HP capacity. 2 Nos. 6 mm dia copper
- iv. Motor above 75 HP. 2 Nos. 25 mm x 3 mm copper tapes.

All switches shall be earthed with two numbers distinct and independent copper wires, tapes as follows:

- | | | |
|------|---|---|
| i. | 3 phase switches 60 amps rating. | 2 Nos. 3 mm dia copper and control panels up to wires. |
| ii. | 3 phase switches, and control panels 63 amps to 100 amps rating. | 2 Nos. 4 mm dia copper wires. |
| iii. | 3 phase switches and control panels 125 amps to 200 amps rating. | 2 Nos. 6 mm dia copper wires. |
| iv. | 3 phase switches, control panels, bus ducts, above 200 amps rating. | 2 Nos. 3 mm x 25 mm copper tapes. |

The earthing connections shall be tapped off from the main earthing of electrical installation. The overlapping in earthing strips at joints where required shall be minimum 75 mm. These straight joints shall be riveted with brass rivets & brazed in approved manner. Sweated lugs of adequate capacity and size shall be used for all termination of wires. Lugs shall be bolted to the equipment body to be earthed after the metal body is cleaned of paint and other oily substance, and properly tinned.

33 DRAWINGS

Shop drawings for control panels and for wiring of equipment showing the route of conduit & cable shall be submitted by the contractor for approval of Architect/Consultant before starting the fabrication of panel and starting the work. On completion, four sets of complete "As-installed" drawings incorporating all details like, conduits routes, number of wires in conduit, location of panels, switches, junction/pull boxes and cables route etc. shall be furnished by the Contractor.

34 TESTING

Before commissioning of the equipment, the entire electrical installation shall be tested in accordance with relevant BIS codes and test report furnished by a qualified and authorized person. The entire electrical installation shall be gotten approved by Electrical Inspector and a certificate from Electrical Inspector shall be submitted. All tests shall be carried out in the presence of Owner's site representative. Testing of the panels shall be as per relevant BIS Codes :

35 PAINTING

All sheet steel work shall undergo a process of degreasing, thorough cleaning, and painting with a high corrosion resistant primer. All panels shall then be baked in an oven. The finishing treatment shall be by application of powder coating of approved shade.

36 MEASUREMENT OF ELECTRICAL CONTROL PANELS

Panels shall be counted as number of units. Quoted rates shall include as lumpsum (NOT measurable lengths) for all internal wiring, power wiring and earthing connections from the control panel to the starter and to the motor, control wiring for interlocking, power and control wiring for automatic and safety controls, and control wiring for remote start/stop as well as indication as per the specifications. The quoted rate of panel shall also include all accessories, switchgear, contactors, indicating meters and lights as per the Specifications and Schedule of Quantities.

37 RUBBER MAT

Rubber mat shall be provided in front to cover the full length of all panels. Where back space is provided for working from the rear of the panel, rubber mat shall also be provided at the back of the panel also to cover the full length of panel.

SECTION XVII : QUALITY ASSURANCE,INSPECTION, TESTING AND COMMISSIONING

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.

2 SUBMITTALS

- I. After award of work following information shall be submitted.
 - a. Quality Assurance Program (QAP)
 - b. Works Quality Assurance Programmed (WQAP)
 - c. Field Quality Assurance Programmed (FQAP)
- II. For inspection and testing, submit inspection and testing procedures, programmer, and 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 pre-commission and commissioning.
- V. After commissioning, submit site test records, as-built drawings, manufacturer's operation maintenance manuals and list of recommended spares and tools.

3 QUALITY ASSURANCE CONCEPT AND CONTROL

- I. Minimum requirements for establishing and implementing a quality assurance programmer 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 programmer does not relieve the Contractor's obligation to comply with the requirement of the contract document. If the programmer is found to be ineffective, then the Owner's site representative reserves the right to request for necessary revisions of the programmer.
- 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 programmer (WQAP)
 - c. Field Quality Assurance Programmed (FQAP)
 - d. Quality Plan.
- IV. These documents shall be prepared separately and submitted to the Owner's site representative at the time of starting 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.

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 Programmed
 - c. Organization Structure showing inter relationships.
 - d. Functional responsibilities and levels of authority.
 - e. Lines of communication.
 - f. Customer relations.
 - g. Laboratory Facilities.

5 WORKS QUALITY ASSURANCE PROGRAMME (WQAP)

- I. The WQAP shall identify the Contractor's Quality Assurance Programmed at works applicable throughout all phases of Contract performance, including design, procurement, manufacture, inspection and testing. It shall identify each of the programmer 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 programmer shall include but not limited to :
- a. Organization 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.
 - i. Control of Non-conformances.
 - j. Corrective Action.
 - k. Control of Inspection, Measuring and Test Equipment.
 - l. Handling, Storage, Packaging and Delivery.
 - m. Records.
 - n. Quality Audits.
 - o. After - Sales Servicing.

6 FIELD QUALITY ASSURANCE PROGRAMME (FQAP)

- I. This programmer shall identify the Contractor's Quality Assurance Programmed 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. Organization 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 Test Equipment.
 - p. Records.
 - q. Completion Documents.
 - r. List of recommended spares and tools.
 - s. Personal Training.
 - t. Servicing during Defects Liability Period.

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 programs.
- 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.

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 liaise 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 Programmed, 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.

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 not or 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 their works as per contract specifications.

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 chillers
- 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 witnessed, 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 format 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 is waived.

11 PERFORMANCE TESTS AT MANUFACTURER'S WORKS

- 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 Quantity 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.

SECTION XVIII :PAINTING AND FINISHES

1 SCOPE

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

2 COLOUR SCHEME

| Description | Standard Color& Reference | Lettering Coloring |
|---|--|---------------------------|
| 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 |
| Beltguards | Black and yellow diagonal stripes (45 25 mm wide) | |
| Switchboards - exterior - interior | BS 366 Light Beige White | |
| Machine Bases, Inertia Bases and Plinths | Charcoal Grey | |

SECTION XIX : IDENTIFICATION OF SERVICES

1 SCOPE

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

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) Trifoliate 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 displayed in each plant room showing the plant layout with pipe work, valve diagram and valve schedule indicating size, service, duty, etc.

3 IDENTIFICATION OF SERVICES

Pipe work and duct work shall be identified by color bands 150 mm. wide or color 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.

i. Pipe work Services :-

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

Basic colors for pipe line identification :

| Pipe Line Contents | BS. 4800 Color Reference | Color. |
|--------------------|--------------------------|----------------|
| Water | 12 D 45 | Green |
| Steam | 10 A 03 | Grey |
| Oils | 06 C 39 | Brown |
| Gas | 08 C 35 | Yellow / Brown |
| Air | 20 E 51 | Blue |
| Drainage | 00 E 53 | Black |
| Electrical | 06 E 51 | Orange |

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

| Pipe Line Contents | Color 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° C | 18 E 55/04 D 45/18 E 53 |
| Above 100° 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 33 |
| Sea / River Untreated | Basic Color only |
| Fire Extinguishing | 04 E 53 |

| | |
|-------------------------|------------------|
| Steam Services: | Basic Color only |
| Air : Compressed | Basic Color 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 Color only |
| Electrical Services : | Basic Color only |

In addition to the color 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.

ii **Duct Work Services**

For Duct work services and its insulation the colors 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 | Color | BS.4800 Color 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 / Recirculate 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 color 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 color banding and triangles shall be manufactured from self-adhesive cellulose tape, laminated with a layer of transparent ethyl cellulose tape.

ANNEXURE – II

TECHNICAL DATA (TO BE FILLED BY VENDOR)

| SI.No. | Description | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|-----------------|--|-------|---|-------|----------------------------------|--|--|------------|-------|------------|-------|------|--|--|--|--|-----|--|--|--|--|-----|--|--|--|--|-----|--|--|--|--|-----------------|--------|--|--------|--|--|
| 1 | CENTRIFUGAL WATER CHILLING MACHINE. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| a) | COMPRESSOR. Make Model Type Origin No of compressors Cooling Capacity at ARI (TR) Cooling Capacity at tender conditions (TR) Refrigerant Discharge gas temp ($^{\circ}\text{F}/^{\circ}\text{C}$) Compressor shell test pressure (Kg/cm^2) Quantity of refrigerant for initial charge (KG) Power consumption C.O.P. at ARI C.O.P at tender conditions | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 25%;">Load</th><th colspan="2" style="width: 25%;">lkW/TR at tender design conditions & with ARI relief (per compressor)</th><th colspan="2" style="width: 50%;">lkW/TR at ARI 550/590 conditions</th></tr> <tr> <th></th><th style="width: 12.5%;">Each Comp.</th><th style="width: 12.5%;">Total</th><th style="width: 25%;">Each Comp.</th><th style="width: 25%;">Total</th></tr> </thead> <tbody> <tr> <td style="text-align: center;">100%</td><td></td><td></td><td></td><td></td></tr> <tr> <td style="text-align: center;">75%</td><td></td><td></td><td></td><td></td></tr> <tr> <td style="text-align: center;">50%</td><td></td><td></td><td></td><td></td></tr> <tr> <td style="text-align: center;">25%</td><td></td><td></td><td></td><td></td></tr> <tr> <td style="text-align: center;">Part load value</td><td colspan="2" style="text-align: center;">NPLV =</td><td colspan="2" style="text-align: center;">IPLV =</td></tr> </tbody> </table> | Load | lkW/TR at tender design conditions & with ARI relief (per compressor) | | lkW/TR at ARI 550/590 conditions | | | Each Comp. | Total | Each Comp. | Total | 100% | | | | | 75% | | | | | 50% | | | | | 25% | | | | | Part load value | NPLV = | | IPLV = | | |
| Load | lkW/TR at tender design conditions & with ARI relief (per compressor) | | lkW/TR at ARI 550/590 conditions | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Each Comp. | Total | Each Comp. | Total | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 100% | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 75% | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 50% | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 25% | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Part load value | NPLV = | | IPLV = | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Recommended Range of capacity variation (%) HP/LP cutout set pressures (Kg/cm^2) Type of bearings. Lubrication arrangement Type of capacity control | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

| SI.No. | Description | |
|--------|---|--|
| b) | COMPRESSOR MOTOR: Manufacturer Type Insulation class. HP/K W Power factor Electrical Characteristics with suitable voltage variation RPM. Efficiency Enclosure/protection class. Starter & type Starting current (Amps) Full load current FLA (Amps) Locked rotor current (Amps) | |
| c) | CONDENSER Make & Model Shell Material Tube material Fouling factor (FPS) Water Flow (USGPM) Water temperature In/Out ($^{\circ}$ F/ $^{\circ}$ C) Water velocity in tubes (m/s) Pressure drop (Kg/cm 2) Tube side design pressure (Kg/cm 2) Shell side test pressure (Kg/cm 2) Pressure relief valve set pressure (Kg/cm 2) Capacity of condenser at ARI(TR) Capacity of condenser at design conditions (TR) | |

| SI.No. | Description | |
|--------|--|--|
| d) | EVAPORATOR Make & Model Shell Material Tube material Type (DX / Flooded) Fouling factor (FPS) Water Flow (USGPM) Water temperature, IN/OUT ($^{\circ}\text{F}/^{\circ}\text{C}$) Water velocity in tubes in case of flooded cooler (m/s) Pressure drop (Kg/cm^2) Shell side design pressure (Kg/cm^2) Tube side design pressure (Kg/cm^2) Shell side test pressure (Kg/cm^2) Tube side test pressure (Kg/cm^2) Pressure relief valve set pressure (Kg/cm^2) Shell insulation– Material & Thickness (mm) Capacity of condenser at ARI(TR) Capacity of condenser at design conditions (TR) | |
| e) | DE-SUPER HEATER / HEAT RECOVERY Heat output at design conditions and at 100% cooling load (kW) Hot water temp rise ($^{\circ}\text{F}/^{\circ}\text{C}$) Maximum hot water temperature ($^{\circ}\text{F}/^{\circ}\text{C}$) Hot water flow (cum/hr) De-super heater capacity as a % of total heat rejection of refrigeration cycle Type of heat exchanger (PHE/ Shell & tube) Water side fouling factor (FPS) Hot water pressure drop through de-superheater (Kg/cm^2) | |

| Sl.No. | Description | |
|--------|---|--|
| f) | MICROPROCESSOR CONTROL CENTRE Provide point wise display system, set points etc. Software/Card to interface with BAS (confirm included) | |
| g) | GENERAL. Overall Dimension(M) Length Width Height Operating weight (kg) Service clearance required (M) L x W x H. ARI / Eurovent certified (confirm) Sound pressure level at 3m horizontal distance (dBA) Type of vibration isolators | |

| SI.No. | Description | | |
|--------|---|-----------------------|-----------------|
| 2. | PUMPS | PRIMARY CHILLED WATER | CONDENSER WATER |
| | <p> Maker Model. Origin Type Head (ft.) Capacity (USGPM) Efficiency (%) Pump (RPM) Motor (HP) Motor make. Electrical characteristics Suitable for $\pm 10\%$ voltage variation Motor efficiency Class of insulation. Full load current (Amps) Starting current (Amps) Locked rotor current on Impeller material Type of water seals. Vibration Isolator Operating weight (Kg) Overall dimensions (LxWxH)mm Performance curves for each pump shall be submitted along with the technical submittal. </p> | | |

| SI.No. | Description | |
|--------|--|--|
| 3. | VARIABLE SPEED PUMPING SYSTEM | |
| a) | ADJUSTABLE FREQUENCY DRIVE Make Model Type Origin Motor Rating Rated Current No. of Steps Maximum Output PID Controller Interface with BAS. Fault Indication Dimensions (LxWxH)mm Operating Weight | |
| b) | AUTOMATIC AFD BY PASS : Make & Model No. Country of Origin Type Motor Rating Rated Current Rating of Power disconnect switch. Type of Enclosure | |
| c) | PUMP LOGIC CONTROLLER Make Model Origin Microprocessor No. of Bits. Clock Frequency Power supply | |

| Sl.No. | Description | |
|--------|--|--|
| d) | DIFFERENTIAL TRANSMITTER/SENSOR Make Model Origin. Type Sensing Element Material for pressure & flow rate. Maximum Static pressure Power supply Degree of Protection | |
| e) | SECONDARY CHILLED WATER PUMP Make Model Type Head (ft.) Capacity (USGPM) For SCHWP indicate capacity at varying speed. Efficiency (%) Pump (RPM) Motor (HP) Motor make. Electrical characteristics suitable for $\pm 10\%$ voltage variation Motor efficiency Class of insulation. Full load current (Amps) Starting current (Amps) Locked rotor current on full load (Amps) Impeller material Type of water seals. Vibration isolation Operating weight (Kg) Overall dimensions (LxWxH)mm Performance curves for each pump shall be submitted alongwith the technical submittal. | |

| Sl.No. | Description | |
|--------|--|-----|
| 4. | CLOSED EXPANSION TANK/AIR SEPARATOR Make Capacity (Volume) Material of Construction Make of Air Separator Size of Air Separator List of recommended accessories included. | CHW |
| | Working principle | |

| Sl.No. | Description | |
|-----------|--|--|
| 5. | AIR HANDLING UNIT | |
| a) | <p>Make</p> <p>Type of unit</p> <p>Material and thickness of casing and coating</p> <p>Drain pan material and thickness.</p> <p>Insulation Material for drain pan & its thickness</p> <p>Flexible connection material</p> <p>Type of vibration isolators</p> | |
| b) | <p>Fan</p> <p>Make</p> <p>Type of fan and model</p> <p>Fan wheel blades material and thickness</p> <p>Housing Material and thickness</p> <p>Confirm complete fan motor assembly statically and dynamically balanced</p> <p>Type of bearings.</p> <p>Fan RPM</p> | |
| c) | <p>Motors</p> <p>Make</p> <p>Type</p> <p>Electrical characteristics suitable for voltage variation</p> <p>Motor speed (RPM)</p> <p>Motor Efficiency</p> <p>Class of Insulation</p> <p>If motor operated through VFD, confirm following:</p> <p style="padding-left: 40px;">Motors do not get derated</p> <p style="padding-left: 40px;">Higher size motor is not required.</p> | |
| d) | <p>Cooling Coil.</p> <p>Make</p> <p>Material of tubes</p> <p>Material of fins</p> <p>No of fins/inch</p> <p>Test pressure.</p> | |

| Sl.No. | Description | |
|--------|--|--|
| e) | Air Filters Make Type of filters Filter medium Pressure drop across filters (mm. of water) for Clean as well as Dirty Condition | |
| f) | Operating Data Air Handling Units | |
| | Air Delivered (CFM) Total Static Pressure (mm of water gauge) Fan Absorbed BHP Fan (RPM) Fan Outlet Velocity MPS/FPM Fan Motor HP Coil Face Area (FT ²) Coil Face Velocity MPS/FPM Pressure Drop Across Cooling Coil ➤ AIR SIDE (MM OF WATER GAUGE) ➤ WATER SIDE (KG/CM ²) Number of Rows Water Velocity In Tubes FPM Type of Filters Filter Face Velocity FPM OR MPS filter efficiency (%) & PARTICLE SIZE (μM) Air Pressure Drop In Clean & Dirty Conditions (MM of WG) Type of Heater Heating Capacity (KW) Hot water in/out temperature for hot water coil (°C) Pressure Drop Across Heater / Hot Water Coil ➤ AIR SIDE (MM OF WATER GAUGE) ➤ WATER SIDE (KG/CM ²) No. of rows for hot water coil | |

| Sl.No. | Description | |
|--------|--|--|
| 6. | VARIABLE SPEED FREQUENCY DRIVE FOR AHU & FANS Make & Model No. Country of Origin Type Motor Rating Rated Current Maximum Output Interface with BAS. Confirm in built Harmonic filter fault Indication. Dimensions (mm) No. of Steps PID Controller Operating Weight | |
| 7. | SCRUBBER Make Type Material of Construction of casing Fan Make, Type & Capacity, Motor HP Fan Motor HP Pump Make, Type, Motor HP Internal piping & fittings make & type Eliminator. Efficiency. Operating Weight. Overall dimensions. | |

| SI.No. | Description | | | | | |
|--------|---|---|-----|--------------------|-----|---|
| 8. | FAN COIL UNITS Make Model Type Actual Velocity /TR at HI Speed. MED Speed LOW speed. Coil face area (ft ²) Unit size: L mm W mm H mm Material/Gage Casing Blowers Drain pan with sandwich insulation. Copper Tubes dia Fins/inch Rows of cooling coil pressure drops ➤ AIR SIDE (MM OF WATER GAUGE) ➤ WATER SIDE (KG/CM ²) ➤ Type of filter Motor make Motor H P/RPM Confirm suitability for 230 ± 6% volts Material of flexible connection Type of vibration isolators | 1 | 1.5 | Capacity (TR) 2 | 2.5 | 3 |

| Sl.No. | Description | |
|--------|--|--|
| 9. | COOLING TOWER Make Model Type Capacity TR Water flow rate (USGPM) Approach Deg F Range Deg. F Casing Material Basin Material Eliminators Material Piping Material and size. Mechanical equipment supports material Fill Material Ladder Material Fan dia and RPM Fan Motor Make Type HP RPM Efficiency and class of insulation. Electrical Characteristics suitability for $\pm 10\%$ voltage Full load / current Drift Loss % of water flow. Evaporative Loss % Total makeup water required (USGDM) Water equalizing connection for multiple cooling towers Operating weight Kg. Overall dimensions (M)(LxWxH) Noise level (dB) from cooling tower 10 meter 15 meter 20 meter | |

| Sl.No. | Description | | |
|--------|---|------------------|----------------|
| 10. | FANS | Centrifugal Fans | Axial Flow Fan |
| | <p>Make</p> <p>Model</p> <p>Type</p> <p>Casing Material & thickness</p> <p>Blower/Impeller Material</p> <p>Shaft Material</p> <p>Bearer</p> <p>Vibration Isolators</p> <p>Fan Size and Model</p> <p>Fan speed</p> <p>Fan efficiency</p> <p>Noise level</p> <p>Noise Attenuator</p> <p>Make</p> <p>Type</p> <p>DB reduction at 2 M & 3 M distance from Noise attenuator</p> <p>Motor</p> <p>Make</p> <p>Type</p> <p>Operating speed</p> <p>Motor efficiency and class of insulation.</p> <p>Electrical Characteristics suitability for $\pm 10\%$ voltage</p> <p>Type of starter & make</p> | | |

| SI.No. | Description | | |
|--------|---|------------------|----------------|
| | FANS | Centrifugal Fans | Axial Flow Fan |
| | Type of drive Material of flexible connection Type of vibration isolators If motor operated through VFD, confirm following: Motors do not get derated Higher size motor is not required. | | |
| | OPERATING DATA Fan model Fan CFM Fan Outlet Velocity (FPM) Static Pressure (mm) Fan RPM Noise Level (db) db Reduction by Attenuator Resultant Noise Level (db) BHP Limit Load HP Motor HP Full Load Current (amps) Starting Current (amps) | | |
| 11. | PROPELLER FANS/ROOF EXTRACTORS Manufacturer Motor HP Capacitors provided. Speed Regulator for single phase fans Gravity louvers Single phase preventer for 3 phase fans Back draft damper Bird Screen Wire guard Noise level | | |

| 12. | CONTROLS | | |
|-----|---|-------|-------|
| | 2 Way Valve | AHU's | FCU's |
| a) | Make of valve Model Type (Proportionate/Snap Acting) Modulating Motor make Model Spring return function Pressure rating Voltage of motor Transformer provided Valve linkage make and model. | | |
| b) | Thermostat for Fan Coil Unit/AHU Make / Type Model Cooling/heating or cooling only Range Differential Fan Speeds Subbase provided Electrical characteristics | | |
| c) | Other controls make and model of following controls/instruments. Flow switch Pressure gauge Thermometer Static pressure gauge Expansion valve Electronic thermometer | | |

| Sl.No. | Description | |
|--------|---|--|
| 13. | ELECTRICAL ACCESSORIES Make of the following: Motor Control Centre (Electrical Panel) Vacuum circuit breaker Air circuit breaker MCCB MCB Rotary switch Soft Starter Auto-transformer Starter Automatic Star Delta Starter Direct on line Starter Contactor Current Transformer (cast resin type) Single phase preventer Push Button Change over switch Ammeter & Voltmeter KWH meter Relay Indication lamp Cables Wires Variable Frequency Drive. | |

| | | | |
|------------|--|------|----------|
| 14. | WATER PIPING | | |
| a) | Make & class of pipes Pipe Wall thickness | | |
| b) | VALVES & STRAINER Butterfly valves Gate valve Globe valve Check valve Ball valve Ball valve with strainer Balancing valve Pot Strainer Y-Strainer | MAKE | MATERIAL |
| c) | Pressure Gauge Make Range Dial Size | | |
| d) | Thermometer (Make/Type & Range) | | |
| e) | Flow Meter Type and Make Size of flow meter | | |

| Sl.No. | Description | |
|--------|---|--|
| 15. | GALVANISED STEEL SHEETS Make Thickness/Gage Class of Galvanizing | |
| 16. | GRILLES / DIFFUSERS / DAMPERS Make, material and gauge of the following: Fire damper, rating, make of damper motor Smoke damper, rating, make of damper motor Grilles/Diffuser Slot Diffuser Duct Damper Fresh Air Damper | |
| 17. | INSULATION Manufacturer Duct acoustic lining material & density Duct insulation material & density Pipe insulation material & density | |
| 18. | VIBRATION ISOLATION SYSTEM Manufacturer Type Stiffness coefficient and Deflection Vibration isolation efficiency (%) Material of flexible connection at Pumps Chillers Expansion Joints | |