SPECIFICATIONS FOR ENVIRONMENTAL CONTROL SYSTEM INCLUDING ELECTRICAL WORKS

TABLE OF CONTENTS FOR ECS ITEMS

Section A00 : General Specification for Environmental Control System

A00.1. General

A00.1.1. Description

A00.1.1.1. This section specifies the requirements for furnishing, installing, testing and commissioning of the Environmental Control System for Mass Rapid Transit System (MRTS) authority.

A00.2. Quality control

A00.2.1. The following standards shall be applicable in general to each equipment and component of the ECS. Specific standards are indicated in the particular specification of each equipment.

A00.2.1.1. Anti-Friction Bearings Manufacturers Association (AFBMA).

9	Load Ratings and Fatigue Life for Ball Bearings.
11	Load Ratings and Fatigue Life for Roller Bearings.

A00.2.1.2. Air Moving and Control Association (AMCA):

210	Laboratory Methods of Testing Fans for Rating.
300	Test Code for Sound Rating of Air Moving Devices
301	Method for Publishing Sound Ratings

A00.2.1.3. American National Standards Institute (ANSI):

S12.34	Survey Methods for Determination of Sound Power Levels of Noise Sources.
B46.1	Surface Texture, Surface Roughness, Waviness and Lay, Part 1.
C1	Specification of General Requirements of a Quality Program
S12.36	Survey Methods for Determination of Sound Power Levels of Noise Sources
Z49.1	Safety in Welding and Cutting
Z55.1	Grey Finishes for Industrial Apparatus and Equipment

A00.2.1.4. American Welding Society (AWS):

D1.1	Structural Welding Code - Steel.
D1.3	Structural Welding Code - Sheet Steel.

A00.2.1.5. American Societyfor Testing and Materials (ASTM):

A 36	Structural Steel
A 123	Zinc (Hot Galvanised) Coatings on Products Fabricated from Rolled, Pressed and Forged Steel Shapes, Plates, Bars, and Strip.
A 193	Alloy-Steel and Stainless Steel bolting Materials for High-Temperature Service
A 194	Carbon and Alloy Steel Nuts for Bolts for High-Pressure and High-Temperature Service

A 239 Locating the Thinnest Spot in Zinc (Galvanised) Coating on Iron or Steel Articles by the Preece Test (Copper Sulfate Dip).

A 276 Stainless and Heat-Resisting Steel Bars and Shapes

A 525 Steel Sheet, Zinc Coated (Hot Galvanised) by the Hot-Dip Process.

A 588 High Strength Low Alloy Structural Steel with 345 MPa Minimum Yield Point to 100 mm Thick.

A 666 Authentic Stainless Steel, Sheet, Strip, Plate, and Flat Bar for Structural Applications

B 247 Certification for Aluminium Alloy Die Forging, Hand Forging and Rolled Ring Footing.

B 686 Aluminium Alloy Castings, High Strength

E 84 Surface Burning Characteristics of Building Materials

E 94 Radiographic Testing.

E 138 Wet Magnetic Particle Inspection.

E 155 Reference diographs for Inspection of Aluminium and Magnesium Castings.

A00.2.1.6. Institute of Electrical and Electronic Engineers (IEEE):

85 Standard Test Procedure for Airborne Sound Measurements on Rotating Electric Machinery

112 Test Procedure for Polyphase Induction Motors and Generators.

519 Recommended Practices and Requirements for Harmonic Control in Electric Power Systems.

A00.2.1.7. Military Specifications (Mil. Spec.):

MIL-P-24441/A General Specification for (Ships), Paint, Epoxy Polyamide.

MIL-P-24441/1A Paint, Epoxy Polyamide, Green Primer, Formula 150, Type 1.

MIL-P-24441/2A Paint, Epoxy Polyamide, Exterior Top Coat, Haze Grey, Formula 151, Type 1.

A00.2.1.8. National Electrical Manufacturer's Association (NEMA):

ICS-1, General Standards for Industrial Control and Systems.

ICS-1.1, Safety Guidelines for the Application, Installation and Maintenance of Solid-State Control.

ICS-2, Industrial Control Devices, Controllers and Assemblies.

ICS-3, Industrial Systems.

MG-1, Motors and Generators.

MG1-12.54 Efficiency

A00.2.1.9. Steel Structures Painting Council (SSPC):

PA-1, No. 1 Shop, Field and Maintenance Painting.

PA-2, Method for Measurement of Dry Paint Thickness with Magnetic Gauges.

SP-1, Solvent Cleaning.

SP-2, Hand Tool Cleaning.

SP-3, Power Tool Cleaning.

SP-6 Commercial Blast Cleaning

SP-10, Near White Blast Cleaning.

PA-1 Shop, Field, and Maintenance and Painting

PA-2 Method for Measurement of Dry Paint Thickness with Magnetic Gauge

A00.2.1.10. International Standards Organisation (ISO):

ISO 281 Rolling bearings: dynamic load ratings and rating life

ISO 1680 Test code for the measurement of airborne noise emitted by rotating electrical machinery: engineering method for free field conditions over a reflecting plane

ISO 5135 Noise: Air distribution and diffusion

ISO 8821 Mechanical vibration: balance. Balancing shaft and fitment key convention

ISO 117 Method of testing the performance of jet tunnel fans

A00.2.1.11. Federal Specifications (FS):

TT-P-645A Primer, Paint, Zinc Chromate, Alkyd Type

A00.2.1.12. Underwriter's Laboratories, Inc. (UL):

508 Industrial Control Equipment.

A00.2.1.13. International Electro technical Committee (IEC)

IEC 34-1 Rotating electrical machines: rating and performance.

IEC 34-5 Rotating electrical machines: classification of degrees of protection provided by enclosures of rotating electrical machines

IEC 34-6 Rotating electrical machines: methods of cooling (except traction engine)

IEC 34-7 Rotating electrical machines: classification of types of constructions and mounting arrangements (except traction engine)

IEC 34-8 Rotating electrical machines: Terminal markings and direction of rotation

IEC 34-9 Rotating electrical machines: noise limits

IEC 34-14 Rotating electrical machines: mechanical vibration of certain machines with shaft heights 56 mm and higher. Measurement, evaluation and limits of vibration.

IEC 85 Thermal evaluation and classification of electrical insulation

IEC 892 Effects of unbalanced voltages on the performance of three-phase cage induction motors

A00.2.1.14. Associated Air Balance Counsil standard.

A00.2.1.15. American Society of Heating Refrigeration and Air-Conditioning Engineers

A00.3. Not used

A00.4. Tools

A00.4.1. The Contractor shall provide a list of tools and test equipment for the repair of any special apparatus and proposal for conducting system acceptance testing and to support the extended period of trial running.

A00.5. Training of operating and maintenance personnel

A00.5.1. Prior to final inspection or acceptance, the contractor shall train and instruct designate operating and maintenance personnel in the operation, adjustment, and maintenance of all equipment and systems.

A00.5.2. The contractor shall explain to O&M personnel, in full and to their complete understanding, all procedures necessary to operate and maintain all equipment and systems on a continuing basis.

A00.5.3. The contractor shall Prepare and review the contents of the O&M Manuals with O&M personnel in full detail to explain all aspects of the Manual and the operation and maintenance of all equipment and systems.

A00.6. Submission of drawings

A00.6.1. The Contractor shall furnish detailed/schematic drawings which shall include but not limited to:

1. Fabrication drawings
2. Interlock drawings
3. Erection drawings
4. Wiring drawing
5. Spare parts drawings with part numbers
6. As built drawings

A00.7. Maintenance

A00.7.1. A maintenance plan shall be provided which shall include the following:

A00.7.1.1. Operating and maintenance instructions which shall describe the procedures for operating and maintaining each item, unit/equipment and which shall include all technical data for its operation, routine inspection/survey, routine maintenance, procedures for removal and replacement of components and test running.

A00.7.1.2. Not used

A00.7.1.3. Special tools, jigs or fixings required for dismantling and test/diagnostic equipment performance monitoring.

A00.7.1.4. Training requirements

A00.7.1.5. Manpower plan required for maintenance

A00.7.2. The documentation included within the various operation and maintenance manuals being supplied shall include sections as appropriate to the specific equipment and systems being provided:

A00.7.2.1 Operating/User manuals: Broken into as many sub-sections as may be necessary and providing sufficient information to enable non-technical staff to exploit fully the facilities of each system.

A00.7.2.2 Workshop manual: Installation and circuits description, full schematics, circuits, wiring diagrams, mechanical construction drawings and itemised parts list to enable all maintenance rectification and setting-up to be carried out.

A00.7.2.3 Software system manuals: Each software package and each piece of equipment which incorporates programmable devices and for which bespoke software has been prepared specifically for this application.

A00.7.2.4 Equipment room manuals: All wiring diagrams and circuits, equipment layout, terminal and cable listing and including such external equipment as may be necessary for completeness.

A00.7.2.5 Maintenance and Services Manuals: To specify requirements, procedures and servicing intervals for planned preventative maintenance and in addition to convey sufficient information on equipment principles and practice to enable first line fault diagnosis and rectification by technician staff.

A00.7.2.6 The Operating/User Manuals shall be provided in both the English and Hindi languages. Other technical manuals shall be supplied in the English language only.

A00.7.2.7 Interactive Manual

A007.2.7.1 The contractor shall submit in English language Interactive Electronic Technical Manuals (IETMs) to manage technical documentation to manage technical documentation. IETMs shall compress volumes of text into CD-ROMs which may include sound and video, and shall allow readers to locate needed information rapidly than in paper manuals.

A007.2.7.2 This IETM shall follow the structure and format of a printed book, with indexes and table of contents that are hyprlinked into the content of the document. All figures, tables and section references shall be linked.

A007.2.7.3 The data to be stored in relational databases, obtaining benefits of data integrity and removal of data redundancy. Relationships in the content that are presented as hyperlinks are mapped directly to relations in the database scheme. The IETM shall be able to change the content dynamically based on user's navigation and input through the content; the content may now be user specific.

A00.7.3. Asset identification

A00.7.3.1. All items of equipment shall have attached to it a rating plate or be indelibly labelled or otherwise identified to show its type, serial number, version, function, location, rating or limitation as appropriate.

A00.7.3.2. Removable modules shall have the same identification on the fixture to which the module is attached. The identification plate or label on the fixture shall be adjacent to the identification plate of the module such that it will not be obscured when the module is in place.

A00.7.3.3. Prominent labels will be provided on equipment to indicate where any hazardous situation could arise due to fluctuating voltage level, air pressure, maladjustment, maloperation, etc.

A00.7.3.4. In general, all labels shall be in both English and Hindi languages.

A00.7.3.5. All equipment and software, down to the line replaceable units, shall have a unique identification number that is capable of being identified electronically and manually.

A00.7.4. Standardisation

A00.7.4.1. Where practical and as part of the general design philosophy to minimise the number of efficient components used on the plant and equipment supplied for the Contract, similar plant and equipment will be replaceable/interchangeable, of modular design and adaptable and extendable.

A00.7.4.2. To this end, the following principles shall apply:

- Operating system shall be uniform for all systems/sub-systems
- Standards for maintenance planning shall be uniformly categorised
- Uniform standard shall be designated for procurement, replacement stocking and availability
- Equipment and accessories shall be provided with uniform standard spare capacity, protection
- Piping and cabling shall carry standard colour coding for identification and categorisation for each kind of use/type. Similarly, a standard procedure shall be followed for identification of each category of equipment while marking and numbering each category of equipment.

A00.7.4.3. Test standards shall be framed such that all the plant and equipment meets the same test criteria. To ensure that this will be the case the following shall apply:

- Type testing, routine testing and endurance tests shall be carried out under similar conditions
- Test evaluation and performance shall be compared with standardised acceptance criteria.

A00.8. General requirements for products

A00.8.1. System description

A00.8.1.1. The ECS consists of an Air-Conditioning System and a station ventilation system.

A00.8.1.2. The AC system shall be a centralised chilled water air conditioning system. Its central chilled water plant shall be located in the ancillary building located over ground adjacent to the station. The chilled water pipes from the AC plant to the station shall run in pipe trenches/tunnel.

A00.8.1.3. The cooling towers shall be located over the ancillary building or at ground.

A00.8.1.4. The central chilled water plant shall finally consist of water chilling units, primary chilled water pumps, secondary chilled water pumps, horizontal split casing condenser water pumps and cooling towers.

A00.8.1.5. The station shall be air-conditioned with the help of air handling units, located in each ECS plant rooms. The concourse and the platform will be served by these AHUs. The fresh air for station shall be provided by axial fans located 1 each in each ECS plant room. The ancillary roomsshall be air conditioned with fan coil units as detailed elsewhere.

A00.8.1.6. The AHU and FCU shall be supplied with chilled water through insulated piping.

A00.8.1.7. The ventilation system consists of the following:

- Trackway exhaust system (TES)
- Smoke exhaust system (SES)

- Ancillary area ventilation system (AVS)

A00.8.1.8. The TES consists of Trackway Exhaust Fans (TEF) connected to ducts running over the track and under the platform. This system under normal circumstances functions as the return air system for the AHU again. In case of fire or smoke these fans will also be utilised for extracting the smoke from Platform. Smoke extraction from the concourse will be through the Smoke extract fans.

A00.8.1.9. The ECS plant room consists of axial fans for supply and exhaust.

A00.8.1.10. All the fans mentioned under the ventilation system are located in the two ECS plant rooms.

A00.8.1.11. The wall-mounted exhaust fans are required to be provided for ventilation of the pump rooms and other areas.

A00.9. Acoustic criteria

A00.9.1. Noise emanating from mechanical services installations shall not exceed the following levels:

A00.9.1.1. At station concourse, platform and ancillary rooms - 55 dBA.

A00.9.1.2. At the surface, when measured at the nearest property line of a residence, commercial building or industrial building :

- urban, residential - 50 dBA.
- urban, mixed - 55 dBA.
- urban, non-residential - 65 dBA.
- Industrial - 65 dBA.

A00.9.2. The noise level from the ventilation system should not exceed 80 dBA in the tunnel when used for applying ventilation under congested traffic conditions or smoke control in an emergency.

A00.9.3. Not used

A009.4 The allowable plant room noise criteria shall be 85db (A).

A00.10. Vibration isolation

A00.10.1. Equipment producing vibrations shall be isolated from the structure by spring or rubber-in-shear vibration isolators. All piping and ductwork connecting to this equipment shall contain flexible connections

A00.11. Equipment Mounting

A00.11.1. Equipment to be mounted on the floor shall be placed on reinforced concrete equipment pads. Minimum pad height shall be 100 mm. The Contractor shall co-ordinate as necessary.

A00.11.2. In cases where units are ceiling suspended, the support system shall be adequately braced to ensure stability during unit start up, operation and shut down.

A00.12. Maintainability

A00.12.1. Items such as knock out panels, double doors, floor drains and access hatches shall be provided by the other Contractors. The Contractor shall co-ordinate as necessary.

A00.12.2. Sufficient clear space shall be provided around equipment to facilitate equipment removal and replacement and to allow for ease in equipment servicing. Provisions shall be made for shaft, tube and filter pull space, access door swings and removal of miscellaneous components.

A00.12.3. Duct access doors shall be provided as required.

A00.12.4. Not used

A00.12.5. Removable duct sections shall be provided to facilitate the removal of electric motors from direct drive axial fans.

- Control system schematic diagrams shall be posted in the vicinity of all control panels.
- Piping system schematic diagrams shall be posted in each plant room.

A00.13. Equipment Identification

A00.13.1. Equipment, control devices, valves and piping systems shall be permanently labelled by the Contractor after installation. The labels shall conform to a system-wide method. This method shall identify individual equipment items and provide information regarding equipment type, equipment function, flow direction and other such data as appropriate. Identification shall be keyed to the control and piping schematics.

A00.14. General Safety Requirements

A00.14.1. The following shall apply to all plants in station air conditioning return ducts:

A00.14.1.1. Local fan motor starters and related operating control devices shall be isolated from the ventilation airflow by a separation having a fire resistance rating of at least one hour.

A00.14.1.2. Thermal overload protection devices shall not be provided in fan motor control circuits for high temperature rated fans.

A00.14.1.3. Wiring for all essential and safety plant shall consist of two separate electrical feeders to an automatic transfer switch. The electrical rating for the transfer switch shall fully accommodate the available short circuit level at the outgoing terminals of the transfer switch. Each feeder shall originate from a different source and shall be separated physically to the maximum extent possible.

A00.14.2. Cables shall not be installed either exposed or surface mounted in air plenums that may carry air at elevated temperatures during fire emergency conditions.

A00.14.3. All conductors shall be enclosed in their entirety in armour sheaths, conduits, cable tray, boxes and cabinets.

A00.15. Voltage Levels

A00.15.1. Voltage for power equipment shall be 415V 3-phase or 240V 1-phase, as required. Motors rated 0.37kW and larger shall be rated 415V, 3-phase, 50Hz. Motors rated smaller than 0.37 kW shall be operated at 240V 1-phase

A00.16. Panel Enclosures

A00.16.1. All panel enclosures shall be of sturdy and robust construction to the best standards and practice to accommodate and support all equipment mounted on them without vibration or movement. Structural members shall not obstruct access to equipment, units nor sub-assemblies. Access doors to cubicles shall be equipped with integral locks.

A00.16.2. All underground electrical enclosures shall be furnished with a high standard of resistance against moisture and dust penetration to ensure reliability of the enclosures.

A00.16.3. All parts and pieces of the enclosures shall be free from sharp edges or burrs. All holes in metalwork shall be protected by substantial grommets or bushes to protect wiring passing through them.

A00.17. Location and space

A00.17.1. Adequate space shall be provided for working clearances and service aisles, where required, and for removal or replacement of the equipment.

A00.18. Service life

A00.18.1. All equipment, cables and wiring shall be designed, manufactured and installed so as to secure a service life as shown below:

A00.18.1.1.	Main switchboards	30 Years
A00.18.1.2.	Sub – main switchboards	30 Years
A00.18.1.3.	Cables	30 Years
A00.18.1.4.	Luminaries	20 Years
A00.18.1.5.	Tray, trunking and supports	30 Years
A00.18.1.6.	All othe equipments	minimum 20 Years

A00.18.1.7. The electronic equipments used in BMS shall have a service life of 10 years.

A18.2 Not used

A00.19. Not used

A00.20. Execution

A00.20.1. Examination

A00.20.1.1. Prior to installation of any equipment on site, the Contractor shall ensure that the area where the plant or equipment is located is in a safe condition for installation to commence.

A00.21. Site preparation

A00.21.1. All site preparatory work shall have been carried out prior to the commencement of the installation.

A00.21.2. Such work shall include the following:

A00.21.2.1 The preparation of all fixings and drilling of any holes required

A00.21.2.2 Cutting and forming of holes for services through walls, floors, ceilings, partitions, roof, etc

A00.21.2.3 Cutting and forming of chases, recesses, in floors, walls for the services

A00.21.2.4 Formation of concrete bases, plinths, for plant and equipment

A00.22. Installation

A00.22.1. Any special requirements for the installation of the equipment will be advised to the Engineer

A00.22.2. All components shall be sized to fit through all plant room access doorways

A00.23. Testing and commissioning

A00.23.1. General

A00.23.1.1. An approved Commissioning Specialist shall undertake the entire commissioning and performance testing of ECS installation. The Contractor shall at all times be responsible for the supervision of the Commissioning Specialist's work and shall ensure satisfactory completion of commissioning and recording results.

A00.23.1.2. The Employer will be given the opportunity to witness all tests. A minimum of 6 weeks advance written notice of tests shall be given.

A00.23.1.3. Any defects of Workmanship, materials, performance, maladjustment, non-compliance with this specification or other irregularities which become apparent during the tests or commissioning shall be rectified by the Contractor, at its own expense, until the whole Works is free from defects and in full working order to the complete satisfaction of the Engineer.

A00.23.1.4. The Contractor shall provide all instruments, and sufficient evidence of the accuracy of the test instruments shall be provided. Test methods shall be demonstrated to the Enginner where required.

A00.23.1.5. The Contractor shall submit to the Engineer a schedule detailing the equipment, which he proposes to use in the testing and commissioning of the services and the test methods to be employed.

A00.23.1.6. Testing and commissioning of major items of proprietary plant or specialist equipment will be carried out by the suppliers personnel and witnessed by the Commissioning Specialist. The Engineer will be advised of such advised of such activities.

A00.23.1.7. Test results will be recorded on approved Commissioning certificates

A00.23.1.8. All test and commissioning instruments will be provided by the Contractor or its Commissioning Specialist, and certified evidence of the accuracy of the test instruments will be provided. The Contractor will submit to the Engineer a schedule detailing the equipment which he or its Commissioning proposes to use in the testing and commissioning of the services and the test methods to be employed.

A00.23.1.9. Instruments for testing will include as a minimum the following:

- Anemometer (range 1.5m/s to 13 m/s)
- Inclined tube anemometer
- Pitot tubes of various lengths to suit duct sizes
- Mercury in glass thermometers
- Weekly recording thermometers
- Weekly recording R.H. meters
- Specially mounted anemometers fixed in a conical sheet metal sheet box hood for measuring accurately air low from diffusers
- Ammeter, Tachometer
- Vibration and Noise testing instruments
- Surface contact dial indicating pyrometer

A00.23.2. Site tests

A00.23.2.1. The testing of chilled water systems will be carried out to ensure safe operating conditions consistent with design performance. Site testing shall include inspection and testing of welding and brazing, pressure testing for soundness of hydraulic system and air leakage testing of ductwork systems.

A00.23.2.2. Unless otherwise indicated, water (other than treated water), and electricity necessary for the operation of the plant during site testing shall be provided free of cost to the Contractor.

A00.23.2.3. Installations or sections of air or water distribution systems which will be embedded in the structure or concealed in permanently sealed ducts, trenches, roof spaces, etc, will, in addition to the above specified tests, be individually tested as they are installed and before being embedded or concealed.

A00.23.2.4. Vibration transmission-break equipment will be thoroughly checked for correct installation and alignment, and will be statically tested to ensure that suspensions and/or connections operate as intended. Any unacceptable vibration apparent during plant operation will be corrected.

A00.23.2.5. Wiring terminations to control equipment will be checked for compliance with the wiring diagrams and for interlocking with other equipment. Any faults will be rectified unless associated with wiring carried out under separate Contract in which case they will be recorded and the details passed to the Engineer for action.

A00.23.3. Cleaning

A00.23.3.1. Pre-commissioning cleaning and flushing shall be carried out prior to start-up. Final cleaning of the chilled water system shall be carried out by circulation of a chemical solution.

A00.23.3.2. All pipes, valves and fittings will be thoroughly cleaned of rust, scale and other foreign mater before erection. All pipework systems will be washed through and thoroughly cleaned as each section is completed with a final cleaning when the whole pipework system is connected up and before being put into service. After cleaning of completed systems, all strainers will be opened and cleaned. Any damaged strainer screens shall be replaced.

A00.23.3.3. Ductwork systems will be cleaned by blowing out using the supply air fan. No fan will be started until cleaning is to commence. Filters made dirty after completion of cleaning will be cleaned or replaced if required.

A00.23.3.4. Cleaning will be completed before the connection of terminal units and fittings.

A00.23.3.5. Duct spigots ends will be temporarily fitted with securely fixed fine mesh covers to collect airborne particles for disposal as directed by the Engineer.

A00.23.4. Hydraulic tests

A00.23.4.1. All services will subject to a hydraulic pressure test at the pressure stated in the particular specification for the service concerned. Where no pressure is indicated, the pressure will be 1.5 times the maximum working pressure specified or 1.5 times the working head where a maximum pressure is not specified. All safety valves, pressure/altitude gauges will be effectively isolated or removed prior to the test and subsequently refitted.

A00.23.4.2. For a satisfactory and acceptable hydraulic test, the pressure will be maintained for a period of 24 hours without loss of pressure (taking into account allowable expansion/contraction due to temperature change), after dealing with any weak joints, defective fittings and pipes disclosed by the initial application of the test. All sections of the work and joints will be accessible for inspection and all welds will be hammer tested.

A00.23.4.3. Certificates for all hydraulic tests made on site will be forwarded to the Engineer for approval and such approval must be obtained before any thermal insulation is applied.

A00.23.4.4. All tests certificates will be signed by the Contractor and by the Engineer who witnesses the tests.

A00.23.5. Air flow balancing

A00.23.5.1. All ventilation systems will be commissioned in accordance with the procedures recommended in ASHRAE/SMACNA/AABC.

A00.23.5.2. Records of commissioning results shall be provided to the Engineer which will detail the recorded air volume and percentage deviation from design air volume, for each supply and extract terminal. Wet and dry bulb temperature measurements will be taken in all room served by air supply systems, and the results indicated on the schedule of commissioning results, together with external ambient wet and dry bulb temperature recorded at hourly intervals over the measuring period.

A00.23.6. Distribution systems-ductwork

A00.23.6.1. Smoke tests will be conducted on all air distribution systems to ensure correct air diffusion from outlet terminals.

A00.23.6.2. After the air systems have been regulated, all dampers will be labelled and quadrants indelibly marked to show the correct setting. Filters will be checked and where necessary, changed or cleaned. The regulation of a system will be achieved initially by change of drive pulleys. Any minor regulation may be obtained by adjusting the fan discharge damper. Additional dampers, which may required for correct air balancing, together with associated works, will be provided at no additional cost to the Employer.

A00.23.6.3. After all air systems have been regulated, the final settings are to be recorded on the Commissioning Certificates provided.

A00.23.7. Fluid circuit balancing

A00.23.7.1. All systems will be fitted with the working fluid, vented as necessary and brought to a state of complete readiness for the system balancing procedures.

A00.23.7.2. All water circuits will be balanced by means of the regulating valves provided and flow rates will be determined on a temperature and pressure drop basis. Flow through pumps will be measured by relating pressure drop across the pump to the Manufacturers tests curves. A copy of the test curve indicating the final operating point shall be provided. Water system will be balanced in accordance with ASHRAE.

A00.23.7.3. Upon completion of balancing and testing operations temperature measurements will taken in all rooms and reading tabulated in schedule form together will hourly ambient external temperature readings taken over the measuring period.

A00.23.8. Refrigerant circuits

A00.23.8.1. If not already carried out at works, all refrigerant systems will be vacuumed and charged with gas/oil in accordance with equipment supplier recommendations.

A00.23.8.2. All electrical circuits (power and control) will be checked for correct functioning of control of the refrigerant system. Similar checks will be carried out for the control panel, local panel (dimensional and functional), etc.

A00.23.9. Chill tests

A00.23.9.1. All chilled installations will after an acceptable hydraulic test, be subjected to a chill test at a minimum operating temperature conditions for a period of four hours, and then allowed to heat up. No leaks will develop at any point in the system.

A00.23.9.2. For a satisfactory test all expansion/contraction devices and support/guide points will be examined and seen to function correctly.

A00.23.10. Condenser/Evaporator/Tank/Receiver vessel tests

A00.23.10.1. All tanks and receiver vessels whether of the pressurised or unpressurised type will be subjected to the site tests defined in the applicable ASME VIII division 1. Where no site test is specified the vessel will be filled with the working fluid at the maximum working pressure and temperature and held for a period of 24 hours.

A00.23.10.2. For a successful test, no leaks will develop nor will there by any visible bulging of the vessel wall.

A00.23.11. Equipment output tests

A00.23.11.1. All items of equipment that have a specified output (or throughout) will be tested and the output or throughout recorded, the method of calculation and all relevant test conditions indicated on the test certificate.

A00.23.11.2. Pump/compressor/motor speed and current tests will be tabulated for each item as applicable.

A00.23.12. Sound level measurements

A00.23.12.1. Reading will be taken to ensure that the required noise ratings are not exceed. Representative areas will be selected by agreement with the Engineer.

A00.23.12.2. The acoustic performance of items of plant where limitations on permitted noise levels are specified and the noise transmission from plant room areas will be measured, recorded and the results assessed.

A00.23.12.3. Wherever necessary, when measuring room sound levels, normal continuous background noise from sources other than the installation will be taken into account. Measurements relating to plant and equipment will generally be taken 1.5 m from the item.

A00.23.12.4. Results of octave band analysis will be submitted on noise rating curve charts for each individual space.

A00.23.13. ECS performance testing

A00.23.13.1. The Contractor will demonstrate by measurement and recording that an installation, or part of an installation, functions correctly without need of adjustment and is capable of maintaining internal environmental conditions within specified limits under varying plant loading. All tests will be witnessed by the Engineer

A00.23.13.2. The Contractor will submit his proposal for the performance tests to the Employer for approval 6 weeks before start of commissioning. For the duration of performance tests, the Contractor will ensure that all qualified commissioning and other specialist personnel are present and available at all times to make any necessary immediate adjustments and repairs.

A00.23.13.3. Specialised installations including technical rooms, switch rooms and safety critical equipment rooms and computer rooms and other close-control applications, will be required to achieve satisfactory system performance when subjected to artificial internal and external loads in accordance with the procedure laid down.

A00.23.13.4. Comfort and process air conditioning installations will be required to achieve satisfactory system performance in accordance with the procedure indicated.

A00.23.13.5. The plant will be continuously operated for a minimum period of 24 hours before tests are witnessed. The Contractor will confirm to the Employer, giving a minimum period of 24 hours notice, that the installation is ready for witness of performance testing.

A00.23.13.6. The Contractor will be responsible for the supply, fixing, connection and safe operation of sufficient temporary artificial heat load equipment and any instrumentation necessary to demonstrate system performance and for subsequent disconnection and removal from site when the Employer is satisfied that tests are complete.

A00.23.13.7. The Contractor will subject the entire plant to a total continuous run of the duration agreed with the Engineer to ensure that all apparatus, materials and systems are working properly. During the run tests will be carried out to ensure, that all controls, safety devices, operating services and all units are properly adjusted and operating correctly, that design temperatures in the piping system and throughout the air system are established and that the system provide the required internal conditions. The Contractor will assure himself that the design intent is achieved before demonstration to the Engineer. The performance will be evaluated during environmental conditions prevailing at that time.

A00.23.13.8. The Contractor will provide a temporary installation of portable recorders where indicated and simultaneously record temperatures and humidifies for summer and winter design conditions. The location of test instruments shall be approved by the Engineer. The corresponding external conditions will also be recorded whilst tests are in progress. The capacity of refrigeration plant, (including components thereof such as condensers, evaporators, cooling towers), and other air handling plant will also be demonstrated and recorded.

A00.23.13.9. Individual room temperatures shall be measured by mercury-in-glass thermometers located 1.5m above floor level at points unaffected by the influence or draughts or direct radiation from hot or cold surfaces.

A00.23.13.10. Measurements and records of performance test results will be entered on the Commissioning formats and handed to the Employer within a reasonable time after the tests are completed. Copies of the results will be retained on site by the Contractor and be available to other official representative as required.

Section A01: Air Handling Units

TABLE OF CONTENT

A01.1. General

A01.1.1. This Attachment specifies the requirements for furnishing air handling units (AHUs) and appurtenances as specified herein. AHUs shall be the product of a single manufacturer whose name shall appear on the AHUs

A01.2. Quality control

A01.2.1. AHU shall be Eurovent certified. The mechanical performance of AHU shall be as per EN 1886. Rating and performance for units, components and section shall be as per EN 13053. Fans shall be AMCA certified for air and sound performance.

A01.2.2. **Manufacturer's Qualifications**

The AHU manufacturer shall show at least five years of continuous and current experience in the design, assembly, and testing of Air Handling Units.

A01.2.3. **Submittals**

A01.2.3.1. The Contractor shall submit to the Engineer for his review and consent, evidence of the manufacturer's qualifications including, but not limited to the following data:

- Theoretical fan-motor composite performance curves of the AHUs proposed to be furnished under this Contract.
- Fan sound power levels in decibels shall be submitted as hereinafter specified. Sound power levels in the eight frequency bands at design airflow capacity shall not exceed the listed values on the fan schedule shown at each octave band.
- Manufacturer's quality assurance program.
- List of major components proposed to be purchased from other manufacturers, giving name of manufacturer, type and characteristic of each item and applicable data requested.
- Eurovent certified datasheet for each AHU model proposed.

A01.2.3.2. Within 45 days after issue of a Notice from the Engineer, the Contractor shall submit the following for the Engineer review and consent.

- Certified shop drawings for AHUs, fans, motors, fan-motor unit bases, installation drawings, installation instructions, and any additional data required to demonstrate compliance with Contract documents.
- Certificate of Compliance signifying that equipment to be furnished under this Contract meets the requirements specified herein Shop drawings shall indicate weight of each component.
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A01.2.3.3. Within 14 days after successful completion of tests specified herein and of any additional tests conducted at the Contractor's own option, Contractor shall submit the following:

- Certified test results for all factory tests conducted. All test data shall be bound in one report. The test report shall be indexed and cross-referenced in an easily understood manner.
- All records and results of non-destructive examinations made at completion of each examination.

- Field test results

A01.3. Technical and installation requirements

A01.3.1. General

A01.3.1.1. The air handling units shall be of double skin construction, draw through type and shall include separate return air plenum, filter section, fan and coil section.Each AHU have two blowers and partition shall be provided between them.

A01.3.1.2. The units shall be insulated to prevent heat loss, to eliminate panel sweating and to provide a moisture free unit.

A01.3.1.3. The units shall be provided with the access doors with look out glass for fan section and filter section to facilitate easy access to internal components for maintenance and repairs or replacement.

A01.3.1.4. The units shall be provided with drain pan of heavy gauge Stainless steel (SS-316) completely rust and corrosion proof and thermally insulated.

A01.3.1.5. The units shall be of a panelised construction fabricated with galvanised steel suitably welded and reinforced to provide a rigid assembly. The complete units shall be absolutely rust free.

A01.3.1.6. Units ships in sections shall have a minimum of four points of lift. These lift points shall be designed to accept standard rigging devices.

A01.3.2. Fan and Accessories

A01.3.3. The fan shall be AMCA certified backward curved Direct Driven Centriflow Plug Fan with integrated factory fitted VFD (IP20). The wheel shall be fabricated from heavy gauge steel. The fan impeller shall be mounted directly on motor shaft. The fan shall be selected for a low noise level. The impeller shall be statically and dynamically balanced. Fan impeller with motor shall be mounted on a common extruded aluminum base mounted in side the air handling housing on anti-vibration mounts. The fan outlet shall be connected to casing with the help on fire retardant fabric acting as flexible connection for anti-vibration.The fan shall be selected for a speed not exceeding 1800 rpm. The fan outlet velocity shall not exceed 12.7 m/s. The fan outlet shall be provided with a motor operated damper (MOD).

A01.3.2.1. Coils shall be manufactured by the supplier of the AHU. Coils shall be removable by unbolting the panels in the coils section. The cooling coil shall be of seamless copper tubes, not less than 0.5 mm thick and mimimum 12.5 mm O.D. The bends shall be ready made with solder rings on both ends. The coil shall have continuous aluminium dual sine wave fins. Having minimum thickness of 0.15 mm and having hydrophilic coating. The fins shall be spaced by collars forming integral part of the fins. The tubes shall be staggered in the direction of airflow. The fins shall be uniformly bonded to the tubes by mechanical expansion/Hydraullic expansion of the tubes. The coils shall be designed to operate at 17.5 kg/cm^2 working pressure and 150 °C temperature and shall be tested against leaks at a pressure not less than 23 $kg/cm^2$by pneumaticor hydraulic pressurisation of coil. This pressure shall be maintained for a period of 2 hours. No drop should be observed indicating any leaks. The water headers shall be of copper pipes, to connect all the tubes. The headers shall be complete with water In/Out connections, vent plug on top and drain at the bottom. Drainpipe should be of SS-304. Coil tube water velocity shall not exceed 2.5 m/s. Where water velocities of less than 0.60 m/s are encountered, a method of turbulation shall be provided. The coil size shall be designed at an operating air velocity of 2.8 m/s. The coil frames should be of SS-304.

A01.3.2.2. The centrifugal fans shall also comply with with section A12.1,A12.2, A12.3.1 and A12.3.4 of the specifications.

A01.3.4. Filtration

A01.3.3.1. Each AHU shall have filters conforming to the specifications given under:

- High Efficiency filters of 90% efficiency down to 10 micron particle size

For detailed specification of filters see annexure-A to these specifications.

A01.3.5. Drain pan

A01.3.4.1. The drain pan shall be construction of 18 Gauge stainless steel (SS-316) sheets, externally insulated with 12 mm thick closed cell polyethylene/polyurethane insulation with necessary slope to allow for proper condensate removal.

A01.3.6. Coil and filter housing

A01.3.5.1. The cooling coils, special and standard filters, etc., shall all be housed in a separate enclosure of suitable size and length. The inspection doors shall have neoprene rubber T-section, rubber seals, hinges and locking arrangements. The gaps between filter frames and housing shall have synthetic rubber/EPDM packing, to eliminate any air leakage. The filter frame shall of aluminium and filter housing frame shall be of SS-304. All filters shall be provided with additional GI rods to provide more strength. The flat filter section shall be suitable for mounting filters vertically.

A01.3.7. AHU enclosure/housing

A01.3.6.1. The AHU enclosure shall be double skin design with the mainframe work made of extruded aluminium structural section.

A01.3.6.2. Casing shall be of panel construction; double wall type packed with pressure injected CFC free foam insulation (polyurethane)having minimum 50mm ± 2mm thick body panel. Casing framework shall be of modular galvanized iron, aluminium or Approved equal pentapost double skin construction. Outer skin shall be minimum 1.0 mm galvanized steel sheet while inner skin shall be minimum 1.2 mm galvanized steel sheet. The sheets should have a minimum galvanisation of 275 GSM. The outer skin and inner skinshould be precoated or powder coated on the exposed side.

A01.3.6.3. Each section shall be provided with separate access panel of suitable size. The access panel shall be hinged type with heavy-duty stainless steel / die cast alumminium hinges and handles made of nylon. The handles shall be self-tightening type to ensure leak proof closing. The access door should have provision of look out glass.

A01.3.6.4. The opening for access doors and gaps between sections shall be provided with the neoprene rubber double ripped/T-gaskets fixed in grooves in the extruded sections.

A01.3.6.5. The sandwich panels shall be bolted from inside on to the framework with soft rubber gaskets in between to make the joints airtight. All fasteners used should be of stainless steel.

A01.3.6.6. Details of AHU Access Door, Air Vent, Drain Plug for Coil Header, pulley, belts and door guard to be provided.

A01.3.8. Fan motor

A01.3.7.1. Fan motors shall be IE-02 Type, 415±10% Volts, 50 cycles, 3 phase, squirrel-cage, totally enclosed fan cooled with IP-55 protection.

A01.3.7.2. Motor shall comply with IS / IEC-60034.

A01.3.7.3. Motor shall be especially designed for quiet operation and motor speed shall be between 4Pole to 6 Pole. Motor shall be VFD compactable type.

A01.3.9. Accessories

A01.3.8.1. Each air-handling unit shall be complete with the following accessories:

- Stem type thermometers at coil inlet and outlet, with tubing and gauge cocks. (Priced Separately)
- Pressure gauge with cock at inlet of the coil, with tubing and gauge cocks. (Priced Separately)
- Butterfly valves at inlet of the coil and balancing valve at outlet of coil. (Priced Separately)
- Drain line from the unit upto floor trap. (Priced Separately)
- Automatic air Vent Valves on pipes. (Priced Separately)
- Damper at inlet and outlet of AHU (Priced Seperately)
- Fire retardant Flexible connection between the fan outlet and duct.
- Metallic plate sandwiched between Neoprene Rubber pad shall be used between AHU and foundation.

A01.3.10. Unit paint

A01.3.9.1. Not used

A01.3.9.2. Unit casing exterior shall be provided with standard colour as approved by the Engineer.

A01.3.11. Limitations

A01.3.10.1. The air velocity across the cooing coil and filter shall not exceed 2.8 m/sec.

A01.3.10.2. The fan outlet velocity shall not exceed 12.7 m/sec.

A01.3.12. Execution

A01.3.11.1. The air-handling unit shall be tested to measure air quantity and coil performance by measuring temperature difference, water pressure drop across coil and then calculating the capacity.

A01.3.11.2. Cooling coils testing

- Identification of materials. The physical & chemical test certificates shall be submitted for consent of the Engineer.
- Checking of mechanical bonding of fins to tubes.
- Pneumatic or hydraulic pressure test on coil 23 kg/cm² for 2 hours.
- Dimensional check.

A01.3.13. Filters testing

A01.3.12.1. Test of sample filter elements as per BS-6540/BS EN 779/ASHRAE 52 or latest International governing specification as applicable to ascertain the material quality and filtration efficiency up to the claimed microns size. The detailed testing procedure shall be submitted to the Engineer for consent.

A01.3.14. Inspection during assembly of components for quality of workmanship, painting etc. and final check of AHU shall be witnessed by the Engineer.

A01.3.15. Cooling capacity shall be computed from measurements of air flow and dry and wet bulb temperature of air entering and leaving the coil. Flow measurements shall be by accurate digital anemometer and temperature measurements by accurately calibrated digital thermometer. Cross checks will be carried out by measurement of water flow rate and temperature differential across the coil with designed full water flow through the coil. The design should be verified by the computed results.

A01.3.16. UVC Emitters

A. GENERAL REQUIREMENTS

Supply, Installation, Testing and Commissioning of Emitters System suitable for mounting in AHUs to reduce mold and fungus growth on the coil and keep the coil surface clean eliminating need for coil cleaning programme.

Shall be - Double Ended Type
Each component and product is to be inbound and outbound tested before shipment under Mil Standard 105E and ANSI/ASQCZ 1.4.

tested in accordance with the general provisions of IES Lighting Handbook, 1981 Applications Volume, total output per one inch are length shall not be less than $10\mu W/cm^2$, at one meter, in a 400 fpm air stream of 45 Deg. F.

B. DESIGN REQUIREMENTS

1. Irradiation – Emitters and fixtures are to be installed in sufficient quantity and in such an arrangement so as to provide an equal distribution of UVC energy on the coil and in the drain pan. To maintain energy efficiency, the UVC energy produced shall be of the lowest possible reflected and shadowed losses.

2. Intensity – shall be measured by a Solid State Photodiode UV Sensor at the coil. Calibration wavelength is 254 mm. Accuracy is to be $\pm$ 10% and be NIST traceable, Operating range shall be 30 Deg. F – 158 Deg. F. Read by a display module with a 3.5 digit LCD screen / panel. Irradiance range shall be 0-1999 (x10) W/ cm^2 with a resolution of $10\mu W/ cm^2$. One metering equipment with display module for metering the intensity of proposed UVC emitter shall be provided.

3. Installation – Emitters and fixtures shall be installed downstream of the cooling coil at right angles to the coil fins, such that UVC energy bathes all surfaces of the coil and drain pan. The wiring kit for emitters shall be supplied by manufacturer / strategic business partner / authorized dealers of manufacturer / business partners only.

C. EQUIPMENT

1. Units shall be high output, HVAC type,germicidal UVC light sources, factory assembled and tested. Components shall include a housing, reflector, high efficiency electronic power source, Emitter sockets and Emitter tube, all constructed to withstand HVAC environments.

2. Double ended Unit housings shall be made of 304 stainless steel with Units having electrical connectors on both ends to simplify gang wiring and wiring to power. They shall include mounting holes to assist in securing the fixtures.

3. DE reflectors shall be constructed of high spectral finished aluminium alloy with a minimum 85% reflectance of 254 mm UVC energy.

4. The Emitters shall be designed to operate at 230 V ac/ 50 Hz with a high p.f. They shall be UL listed to comply with UL Standard 1995 and capable of igniting each Emitter at temperatures from 35 – 170 Def. F in airflow velocities to 1000 fpm. They shall be equipped with RF and line noise suppression.

5. Emitter tube shall be of the high output, hot cathode, T5 (15mm) diameter, and medium bi-pin type. They shall produce 95% of their energy at 254 mm and be capable or producing the specified output at airflow velocities to 1000 fpm at temperatures of 35 – 170 Deg. F. **UVC Emitters shall not produce ozone or other secondary contamination.**

D. INSTALLATION

INSTALLATION OF UVC EMITTERS

A. Sufficient No. of Emitters installed on each coil .
B. An interlock switch shall be provided on each access door to the UVC Emitters to turn the lights off when the access is opened.Also manual switching off the UV lights shall be provided to avoid their turning on in case of closure of door by any mean or maintenance purpose.
C. Proper Caution Labels shall be installed on all accesses to the Emitters when installed.

The transformer rectifier must be protected against weather when installed outdoor and its housing shall meet at least IP44 standard.

Power input to the transformer rectifier shall be single phase 230 V, 50 Hz AC. Supply whereas the continuous DC Output from the transformer rectifier must have the maximum capacity of 30 Volt, 3 Amp. For safety reason, DC voltage higher than 30 volt is not acceptable. However, the transformer rectifier rating must be capable of withstanding the continuous maximum current output of 3 amps.

Copper – Silver ionization system

Essentially, the copper-silver ionization system shall consist of a 30V 3A maximum output transformer rectifier to energize the copper and silver electrodes. The electrode set shall be placed in the cooling water sump to discharge the copper – silver ions and to collect the calcareous at the electrode set.

DC cabling – DC cables from the transformer rectifier to the junction box shall be run in either rigid PVC conduit of galvanized conduit. The positive and negative cable must have different colour for identification. From the junction box to the electrodes, the cables shall be run in either rigid or flexible PVC conduit. It is very important that the electrodes must be connected to the transformer rectifier positive terminal and the DC current return must be connected to the transformer rectifier negative terminal.

Electrodes – The electrode set shall be placed inside a plastic container and positioned at the deep sump area to remain fully submerged at all times. The electrodes shall be located away from the outlet of Cooling Tower.

One set of Digital TDS & pH meter must also be provided with each unit to keep a close check on the TDS and pH level of make – up and Recirculation Water

Annexure-A AIR FILTERS

Scope This specification covers air filters to be provided in environmental control systems at different location inside the station.

Codes and Standards Filters shall conform, where applicable, to the following standards:-

(1) UL900 - Standard for test performance of air filter units.

(2) BSEN779 - Particulate air filters for general ventilation. Requirements, testing, marking.

(3) ASHRAE standard 52-76 - method of testing air cleaning devices use in general ventilation for removing particulate matter.

(4) Other standards as specified.

Fire Properties Air filters and their enclosure shall be constructed from materials which conform to the fire property requirements of one of the following standards:-

(1) BS476: Pt. 4 - Non-combustibility Test for Materials;

(2) BS476: Pt. 6 - Method of Test for Fire Propagation for products with indices "I" £12 and "i" £6;

(3) Underwriters Laboratories Inc. UL900 - Test Performance of Filter Units, Class 1 or Class 2;

(4) DIN53438: Pt. 3 - Response to Ignition by a Small Flame, Surface Ignition, Class F1.

General (1) All filters shall be washable type. All filters shall have minimum efficiency of MERV-8 / EU-4.

(2) Filter assemblies shall operate with at least the efficiencies specified in this Section.

(3) Filters shall be complete with robust enclosure, filter frame shall be of aluminium and and filter housing frame shall be of SS304. All filters shall be provided with additional GI rods to provide more strength.

(4) The enclosure shall be constructed and assembled in such a manner that a rigid and durable enclosure for the filter pack is effected.

(5) The periphery of the filter pack shall be continuously bonded to the inside of the enclosing frame thus eliminating the possibility of air bypass.

(6) Filter frames shall be factory fabricated and shall be equipped with gaskets and a minimum of four heavy duty positive sealing fasteners. The gaskets shall be able to prevent air bypass between the filter and frame, between the adjacent frames and between the frames and housing. The fasteners shall be capable of being attached or removed without the use of tools. All gaskets shall have the same fire property requirements as the air filter, as detailed in Clause above.

(7) The housing shall be factory fabricated and assembled. They shall incorporate access doors, extruded aluminium tracks and individual housing frames designed to accommodate standard size filters in efficiency and construction rating specified for the installation.

(8) Type test certificates for each type of filter media intended for use on the installation shall be submitted.

Filter Identification

All filters shall have the following information clearly marked or stamped in a readily accessible location:-

(1) Manufacturer's Name;

(2) Place of Manufacture;

(3) Filter type and model number;

(4) The standard to which the filter has been type-tested.

Washing facilities for washable filters

(1) The Contractor shall provide one set of duplicate cleaning tanks (one to wash, one to rinse). These tanks shall be such as to accommodate all sizes in the Contract.

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

(3) The contractor shall perform cleaning of filters during DLP.

DATASHEET OF AIR HANDLING UNITS	
AHU Capacity (ECS North and South)	As per BOQ
Reference Code / Standard	Fan AMCA-210& AMCA300, Eurovent certified AHU – EN 1886 & EN 13053
Flow Rate	As per BOQ
Total Quantity	As per BOQ
Noise Criteria	Refer to Specification (85 dBA at 1 m distance in plant room)
Tag No	Tag No To Be Marked On AHU With Black Letter. SS Tag To Be Firmly Attached
Thermal Break Profile	As per mfg. Standard
Construction	Sectionalized / Modular Double Skin Type 50mm ± 2mm thick panel
Casing	
Out side	1.0mm
Inside	1.2mm
Insulation	As per specifications
Height of the unit	As dictated by plant room layout – refer to drawings
Number of Sections (functional – not necessarily physical)	1. Fan Section 2. Coil Section 3. Filter Section 4. Mixing box Section 5. Any other section if required
Access Door	Access door to be provided in fan section & mixing box.
Damper	
Type	Non Fire Rated Parallel Blade (Refer the Data Sheet For Damper)
Inlet	One at the suction side (MD)
Outlet	One at the discharge of each fan Motor Operated Damper (MOD)
Modular Frame	Aluminum Alloy
Base Frame	GSS
Drain	
Pan	Stainless Steel 316 (18G) with Insulation
Insulation	Polyurethane Foam / Polyethylene foam
Thickness And Density	12 mm Thick Density 38-40 kg/m^3
Connection	40 mm Connection On One Side
Fan Section	
Fan	
Type	Centrifugal Plug type - Backward Curved Aerofoil

	Construction statically and Dynamically Balanced
Characteristics	Non Over Loading
Number	Two per AHU
Total Pressure	As per BOQ
Blade	As per specifications
Fan Section	
Fan	
Shaft	As per specifications
Outlet Velocity	12.7 m/s (Max) or as per manufacturer standard.
Housing	As per manufacturers standard
Hub	As per manufacturers standard
Mounting	As per Mfg. Std.
Bearings – Shaft	As per Mfg. Std.
Connection	Flame Proof Flexible Connection
Vibration Isolator	Spring Isolators
Accessories	With access door, drain plug spring vibration isolator
Motor	
Type	TEFC Induction Motor IP-55 Protected,IE-2 Efficiency Class
Reference Code / Standard	***As per IEC 60034***
Electric Supply	Three Phase, 415 V, 50 Hz, AC Supply
RPM	1495 (Max)
Mounting	Slide Rails
Coil Section	
Coil	
Valve	2-Port Motorized Valve Each/coil
Entering Water Temperature	8 °C
Leaving Water Temperature	15 °C
Velocity Air	2.5 m/s/or as per manufacturers standard
Air Entering Temp	As per design requirement
Air Leaving Temp	As per design requirement
Test Pressure	23 kg/cm^2pneumatic or hydraulic
No of Rows	Minimum 6 ROWS deep
Tube	Copper, 0.5mm thick, 12.5 mm OD
Coil Mounting	Stainless Steel
Fins	Aluminium 0.15mm thick, Maximum 10 FPI
Type Of Fins	Sinusoidal Wave Pattern with hydrophilic coating
Fin Bonding to Tubes	Mechanical Expansion / Hydraulic Expansion

Filter Section	
Filter	
Frame	Filter frame – Aluminium Filter Housing – SS304
Type	Panel Type.
Media	Non flammable, Non toxic, Low smoke synthetic resign media confirming to UL900, EN-779.
Sealing of Media	By means of epoxy
Efficiency	90% down to 10 micron particle size.

1) Air Handling Units shall be as per specifications, data sheets and drawings.
2) All accessories as per data sheets shall be provided
3) Pressures and Motor ratings are approximate. Vendors shall do their own calculations & offer the equipments as required.
4) Each centrifugal plugfan shall be provided with access panel and drain plug.
5) AHU's Shall be fitted with UVC emitters minimum 20 Tubes

Section A02: Fan Coil Units

TABLE OF CONTENT

A02.1. General

A02.1.1. This section specifies the requirements for manufacturing, furnishing, testing and commissioning fan coil units and appurtenances as specified herein. Fan coil units shall be the product of a single Manufacturer whose name shall appear on all the submittals.

A02.2. Quality control

A02.2.1. Coils shall be AHRI certified.

<u>American Heating & Refrigeration Institute</u>
AHRI 410 Coil performance

A02.2.2. Manufacturer's qualifications

The fan coil units Manufacturer shall show at least five years of continuous and current experience in the design, assembly and testing of fan coil units.

A02.2.3. Submittals

A02.2.3.1. Submit the following to the Engineer for review and obtain a notice of no objection:

- Dimensioned drawings of FCU showing material of construction of each component
- Technical data sheet of FCU giving the sound level, air quantity and power consumed at all the three speed at the stated static pressure and the cooling capacity at the rated conditions indicated.
- Manufacturer's quality assurance program
- Certificate of compliance that the design and fabrication of the FCU to be furnished under this Contract meets the requirements specified herein

- Within 14 days after successful completion of factory tests specified herein and of any additional tests conducted at the Contractor own option, the Contractor shall submit the following:
  - Certified test results for all factory tests conducted. All test data shall be bound in one report. The test report shall be indexed and cross-referenced in an easily understood manner.
  - All records and results of non-destructive examinations made at completion of each examination.
  - Field test results

A02.3. Technical and installation requirements

A02.3.1. General

A02.3.1.1. The FCU shall be complete in all respects and shall generally comply with the specifications as given hereunder.The coil performance shall be as per AHRI-410

A02.3.1.2. The FCU body casing shall be sandwhich type 25±1mm thick of double skin construction concealed ceiling mounting type complete with finned coil, fan section with motor, drain pans, air filters, filter box, etc. Inner skin & Outer skin thickness should be 1.2 mm & 1 mm galvanised sheet steel respectively. The sheets shall also be Powder coated/

Precoated.Insulation material of polyurethane/polyethylene shall be provided between the outer and inner sheets.

A02.3.1.3. All fan coil units shall be demountable from the ceiling void for maintenance purposes without causing damage to the associated ductwork and insulation

A02.3.1.4. All fan coil units shall be selected to suit the limited space within the false ceiling with due considerations to access for maintenance and servicing. Coordinate with all involved parties on Site for the provision of maintenance access panels for the units mounting inside false ceiling.

A02.3.1.5. The drain pan details, control details, installation details, operation & maintenance manual shall be submitted along with the proposal.

A02.3.2. Cooling coil

A02.3.2.1. The coil shall be 4 rows deep, of seamless copper tubes not less than 12.5mm O.D. and 0.5 mm thick encased in SS-304 frame and having copper headers.

A02.3.2.2. The coil shall have continuous aluminium fins having minimum thickness of 0.15 mm.Max 13 Fins per inch. The fins shall have hydrophilic coating and shall be of sinusoidal pattern.

A02.3.2.3. The fins shall be spaced by collars forming integral part of the fins. The fins shall be uniformly bonded to the tubes by hydraulic/ Mehcanical expansion of the tubes.

A02.3.2.4. The tubes shall be staggered in the direction of air flow.

A02.3.2.5. The coil circuit shall be sized for adequate water velocity but not exceeding 1.8m/s. The coils shall be tested against leaks at a hydraulic or pneumatic pressure of 21.0kg/cm^2. This pressure shall be maintained for a period of 2 hours. No drops/bubbles shall be observed indicating any leaks.

A02.3.3. Fan and motor

A02.3.3.1. This shall consist of aluminium impeller of forward curved type, both statically and dynamically balanced, along with properly designed GI sheet casing.

A02.3.3.2. Maximum noise level acceptable shall be 65dB at a distance of 1m from fan.

A02.3.3.3. The two impeller shall be directly mounted on to a double shaft, single phase, multiple winding motor, capable of running at three speeds.

A02.3.3.4. Motor shall be capable of providing at least 3 fan speeds (‘LOW-MEDIUM-HIGH’) and shall be of adequate capacity to prevent over-loading at any speed and duty of the fans. Each fan coil unit shall be equipped with a three-speed fan switch (‘LOW-MEDIUM-HIGH’) and ON/OFF switch for the fan control. The rated performance of the FCU shall be at medium speed.

A02.3.3.5. Motor shall be of the permanent split-capacitor type for direct-on-line starting, and factory wired to a terminal block inside a factory installed junction box. Motor shall be provided with UL listed thermal overload protection. Motor windings and electrical components shall be impregnated or protected to avoid trouble from condensation.

A02.3.3.6. Connection unit or socket outlet shall be provided near each fan coil unit. Location of these electrical power points shall be coordinated so that the connection unit or socket outlet shall be positioned within 1 m from the fan coil unit.

A02.3.3.7. Electrical wiring connection including cables and wiring accessories between the connection unit or socket outlet and the fan coil unit shall be provided.

A02.3.3.8. Electrical cables or wiring installed outside the casing and inside the air stream shall be protected by metallic flexible conduit.

A02.3.4. Drain pan

A02.3.4.1. Every fan coil unit shall be provided with a drain pan that shall be situated beneath the coil and arranged so that all moisture will be collected in the pan. The pan shall project under the entire length and width of the coil including all headers and bends.

A02.3.4.2. The drain pan shall be of double skin construction with 15mm thick panel/casing. Polyurethane/polyethylene insulation sand-witched between 22 G outer and 18 G inner pans of SS-316 accommodating coil connections, valves, and shall be complete with drain connections shall be provided.

A02.3.4.3. The FCU shall also be provided with a secondary drain pan of 18 G SS (SS-316) sheet duly epoxy coated/FRP lined from inside.

A02.3.4.4. Each drain pan shall be fitted with an insulated drain pipe which shall be connected via suitable runs correctly laid to fall to the drainage system. Drain pans shall have copper/SS male connectors for connection to the condensate drainpipes. The drain pipe should be of GI.

A02.3.4.5. The drain pipe should connect to the nearest drain point in the room to be provided by other contractor.

A02.3.4.6. Drain pans shall be large enough to collect all condensate from the coils, return bends and pipe work connections. For units catering for load including a high proportion of latent heat, the size of the drain connection shall be adequate to deal with the condensate.

A02.3.5. Air filter

A02.3.5.1. The filters shall be washable fibre glass/polypropylene air filters with anodised extruded aluminium frames mounted behind the fans in a filter box made of GI sheets.

A02.3.5.2. The efficiency of filters shall be 90% down to 10 microns.

A02.3.5.3. Other requirements of filters shall comply with Annexure ‘A’ of AHU specifications wherever applicable. The additional GI rods shall not be required for FCU filters.

A02.3.6. Water connections

A02.3.6.1. The water lines shall be finally connected to the coil of the fan coil unit by at least 300 mm long type L, seamless, solid drawn copper tubing, with flare fittings and connections

A02.3.6.2. The water connections shall be made so that all the valves installed are accommodated within the extension of the drain pan of the unit. So that, in case of any leak in the valves, the water shall fall into the drain pan and not onto the false ceiling.

A02.3.6.3. The copper piping shall be insulated with polyethylene tubes of suitable size, and all joints shall be sealed with aluminium tapes.

A02.3.7. Noise control

A02.3.7.1. FCU shall be selected for the lowest operating noise level of the equipment.

A02.3.8. Valves

A02.3.8.1. The water valves on inlet line shall have factory fitted valve with integral Y strainer and ball valve with and without strainer assembly. The ball valve and Y strainer shall be of Gun metal/brass..

A02.3.8.2. Return line shall be provided with pPICV. PICV shall comply with specification given in A.10.

A02.3.8.3. Fan coil unit valve set shall be factory fitted and tested with all accessories (PICV, ball valve at return pipe, ball valve with Y strainer at supply and air vent etc) shall be fitted on FCU on site.

A02.3.9. Installation

A02.3.9.1. The FCU shall be installed as per good engineering practice and as per the standard referred.

A02.3.9.2. The power outlet to the FCU shall be provided with an isolator and its location shall be co-ordinated so that it is located with 1 to 1.5m of the FCU.

A02.3.9.3. Each FCU shall be provided with a thermostat positioned in an approved location. The thermostat shall have switches t provide Low-Medium-High fan speeds and a rotating temperature set point selector.

A02.3.9.4. The thermostat shall have an aesthetically made housing/cover.

A02.3.9.5. The cabling and wiring between the thermostat, the FCU and the power point shall be provide in fully concealed metal conduits of approved quality. Free hanging of cabling and wiring shall be kept to the minimum distance possible, and such cables shall be provided with metallic flexible conduits of approved quality.

A02.3.9.6. The end of the flexible conduit shall be properly terminated in the junction box of the FCU and the pipe conduit/switch box at the other end.

A02.3.10. Field tests

A02.3.10.1. After each FCU is installed and ready for pipe connection, the coil shall be tested against leaks at a hydraulic pressure of 21kg/cm^2. The pressure shall be maintained at least one hour, and no drop or leak shall be observed. Repair of coil shall not be permitted.

A02.3.10.2. After the installation work is completed, the following minimum characteristics shall be measured:

- Air quantity at all of the three speeds
- Sound level inside the conditioned space
- DBT and WBT of return air and supply air

DATA SHEET FOR FAN COIL UNIT

Nominal Capacity	As per BOQ
Reference Code / Standard	Coil Performance AHRI – 410
Valve	PICV Assembly (Factory Fitted)
Control Panel	Cordless / Cord Type Remote Control
Sensing Element	Thermostat
Mounting Arrangement	Ceiling Suspended / Wall mounting Type
Outer Housing	GSS with pre-coating/powder coating
Drain Pan	Stainless Steel(SS-316)With Sandwich Insulation(15mm Thick), With Drain Connections
Blower	
Blade	Forward Curved
Air Flow	As per BOQ
Static Pressure	As per BOQ
Shaft	As per manufacturing standard
Bearing	As per manufacturing standard
Drive Arrangement	Direct
Mounting	Shaft Key And Positive Locking Device
Water	
Inlet Temperature	8° C
Outlet Temperature	15° C
Coil	
No of Rows	Four
Tube	Copper (0.5mm thick), 12.5 mm OD
Fins	Aluminum 0.15 mm thick, Max 13 Fins Per Inch Sinusoidal Wave Pattern with hydrophilic coating
Inlet / Outlet Connections	20 mm OD
Coil Test Pressure	21.0 Kg./Sq. cm pneumatic or hydraulic
Motor	
Type	Single Phase Induction Motor
Electric Supply	Single Phase, 220 V, 50 Hz, AC Supply
RPM	As per manufacturing standard
Bearing	As per manufacturing standard
Shaft	As per manufacturing standard
Noise Level	65dBA at 1 meter

Section A03: Chilling Water Units – Centrifugal/ Screw Compressors

TABLE OF CONTENT

A03.1. General

A03.1.1. This section specifies the requirements for furnishing, installing and testing water chilling units with screw compressors and appurtenances as specified herein, including but not limited to:

- Chiller package
- Charge of refrigerant and oil
- Controls and control connections
- Chilled water connections
- Condenser water connections

A03.1.2. The performance curves and other data submitted for the water chilling units proposed to be furnished shall be certified by the American Refrigeration Institute (AHRI). The water chilling units shall be the product of a single manufacturer whose name shall appear on all the technical submittals and it shall be manufactured in a facility whose products are certified by AHRI.

A03.2. Quality control

A03.2.1. Reference standards

A03.2.1.1. Materials and workmanship shall be in accordance with the latest edition of the following standards and codes to the extent specified herein. The publications listed below form a part of these specifications to the extent referenced. The publications are referred to in the text by basic designation only.

A03.2.1.2. American Refrigeration Institute (AHRI)

550/590 Water chilling packages using the vapour compression cycle

A03.2.1.3. American Society of Heating, Refrigerating and Air-Conditioning Engineers

ASHRAE 30-1995	Methods of testing liquid chilling packages
ANSI/ASHRAE 24-1989	Methods of testing for rating liquid coolers
ANSI/ASHRAE 22-1992	Methods of testing for rating water cooled refrigerant condensers
ANSI/ASHRAE 15-1992	Safety code for mechanical refrigeration

A03.2.2. Manufacturer’s qualifications and experience

A03.2.2.1. The water chilling units Manufacturer shall show at least ten years of continuous and current experience in the design, assembly and testing of such units.

A03.2.3. Submittals

A03.2.3.1. Before giving the Manufacturer notice to proceed, the Contractor shall submit to the Employer for review and approval, the name and qualifications of the Manufacturer of water chilling units. Qualification statement shall include but need not to be limited to the following data:

- Manufacturer’s selection software print out for the model of the chilling units proposed to be furnished under this contract as certified by AHRI
- Manufacturer’s computer software print out for performance at part load in steps of 100%, 75%, 50% and 25% as certified by AHRI

- Data sheet showing computation of IPLV as per AHRI
- Data sheet showing computation of NPLV as per AHRI
- The following data shall be imprinted on each data sheet:

  Project title

  Chilling unit designation number

  Chilling unit rated capacity as per AHRI
- Manufacturer's quality assurance program
- Installation and operation manuals

A03.2.3.2 The Contractor shall submit to the Employer a certificate of compliance signifying that equipment to be furnished under this Contract meets the requirements specified herein.

A03.2.3.3 Within 14 days after successful completion of all factory tests specified herein and of any additional tests conducted at the Contractor's own option, the Contractor shall submit the following:

- Certified results for all factory tests conducted. All test data shall be bound in one report. The test report shall be indexed and cross-referenced in an easily understood manner.
- All records and results of non-destructive examinations made at completion of each examination.
- Field test procedures.

A03.3. Technical and installation requirements

<u>A03.3.1.</u> Screw Chillers

A03.3.1.1. Each water cooled chilling unit shall be a standard cooling model and shall comprise:

- Screw compressor
- Shell and Tube Condenser with accessories and supports.
- Shell and Tube chiller with accessories, support and insulation.
- Steel structure as required for assembling/mounting the above.
- Microprocessor based colour control panel with automatic controls and display module with BMS compatible features.
- Accessories as specified/required.
- Interconnecting refrigerant piping.
- Full charge of Refrigerant and oil.
- Soft Starter for the motor.

A03.3.1.2. Contractor shall provide chiller Manufacturer's standard materials and components as indicated by published product information, designed and constructed as recommended by the manufacturer and as required for a complete chiller installation as specified herein. The chiller shall be designed, selected, and constructed to use refrigerant HFC-134a / R-410A (not subject to the Montreal Protocol). Chillers shall meet the capacity requirements specified herein. Refrigerants containing chorine (HCFC's) are not acceptable.

<u>A03.3.2.</u> The chillers shall fit into the space provided and shall be made readily serviceable including where applicable, the provision of marine water boxes and other necessary accessories, etc., to complete the system.

Compressor

A03.3.2.1. Each unit shall have a rotary twin-screw or centrifugal compressor serviceable bolted semi-hermetic type.

A03.3.2.2. The twin rotary screw shall be manufactured from forged steel with precision cast male and female profiles, which are asymmetrical. The profile of screws shall permit safe operation upto a speed of 3000 RPM for 50 Hz operation.

A03.3.2.3. The compressor shall unload from fully loaded to the minimum capacity by means of hydraulically actuated slide valve positioned over both the male and female rotors.

A03.3.2.4. The compressor housing shall be of high grade cast iron, machined with precision, to provide a very close tolerance between the rotors and the housing.

A03.3.2.5. The rotors shall be mounted on antifriction bearings designed to reduce friction and power input. There shall be multiple cylindrical bearings to handle the radial and axial loads.

A03.3.2.6. There shall be built in oil reservoir to ensure full supply of lubricants to all bearings and a check valve to prevent back spin during shut down.

A03.3.2.7. There shall be oil pump or other means of differential pressure inside the compressor for forced lubrication of all parts during start-up, running and coasting for shut down. An oil sump header shall be provided in the casing.

A03.3.2.8. The units shall be complete with automatic capacity control mechanism, to permit modulation between 20% and 100% of capacity range. The Compressor will be designed to operate both on full capacity as well as part capacity without effecting the operating efficiency. The chiller units should be able to modulate cooling capacity to precisely match the load and minimise energy consumption. Chilled water temperature control setting capability will be to 0.1 °F or less

A03.3.3 **Compressor motor**

A03.3.3.1. The driving motor shall be double squirrel cage type or suitable hermetic type as required, protected against damage by means of built in protection devices.

A03.3.3.2. In case of hermetic type, motor shall be liquid refrigerant cooled with internal thermal overload protection devices embedded in the winding of each phase.

A03.3.3.3. If open type motors are used, the Contractor shall ensure that the motor heat loss will not result in excessive increases in temperature of the plant rooms affecting the operation and performance of the chillers and other equipment. The Contractor shall provide at his own expense any additional ventilation/cooling equipment. In addition, the Contractor shall also bear all direct, indirect and associated costs to provide a mechanical room safety alarm, wiring and chiller emergency shutdown shall be included to prevent chiller operation if the room temperature exceeds 40°C.

A03.3.3.4. Motor shall be compatible with the specified starting method.

A03.3.3.5. The motor shall be of minimum efficiency class IE2.

A03.3.3.6. Compressor motor shall be provided with overcurrent, single phasing and phase reversal protection.

A03.3.4 Condenser

A03.3.4.1. Each unit shall have one horizontal shell and tube, water-cooled, multipass condenser, fitted with safety valve, purge valve, and other safety devices.

A03.3.4.2. The shell shall be of welded steel construction fitted with machined steel tube sheets on either ends. The water boxes/end covers shall be marine type of steel or cast iron so that tubes are accessible without dismantling of pipes. The water boxes/end covers shall be removable and plant components shall be arranged so that the space for tube removal is not obstructed.

A03.3.4.3. The tubes shall be at least 12 mm O.D. and at least 24 Gauge thick of seamless copper with integral fins. The tubes shall be supported in the shell to avoid noise and vibrations and the ends shall be properly expanded in the tube sheets to prevent leakage of refrigerant gas.

A03.3.4.4. The water heads shall be of fabricated steel, easy to remove, with suitable baffles for multipass water flow, In and Out connections and gasket to prevent water leakage.

A03.3.4.5. The condenser shall be tested against leaks on both the shell side and the waterside.

A03.3.4.6. The condenser shall be complete in all respects and shall also include:

- Support for mounting.
- Refrigerant In and Out connections.
- Water In, Out and drain connections.
- Relief valve and purge valve.
- Refrigerant Isolation Valve

A03.3.5. **Evaporator**

A03.3.5.1. Each unit shall have one horizontal shell and tube, flooded type cooler complete with accessories.

A03.3.5.2. The shell shall be of welded steel construction fitted with machined steel tube sheets on either ends. End water boxes shall be designed to provide adequate space for water movement such that there is no erosion of the tube ends. In general, this requires the water box end to be domed rather than flat. End box covers shall be removable, and allow easy access for cleaning the tubes.

A03.3.5.3. The evaporator shall either have internally finned copper tubes or tubes with other means for increasing heat transfer surface. The tube shall be supported in the shell by adequate, stiff supports to eliminate vibration and noise. The tube ends shall be mechanically bonded to the tube sheets to prevent leakage of refrigerant gas. The tubes shall have min 19mm O.D and min 24 Gauge thickness.

A03.3.5.4. The water heads shall be made of fabricated steel and the faces ground to a close tolerance to prevent leakage and permit 2,3 or 4 pass operation.

A03.3.5.5. The evaporator shall be tested against leaks both on the shell and the waterside.

A03.3.5.6. The cold parts of the evaporator shall be insulated.

A03.3.5.7. The evaporator shall be complete in all respects and also include: -

- Supports for mounting.
- In and Out connections both for the refrigerant and the water circuit and drain connections.
- Anti fouling device for condenser unit

A03.3.6 **Oil recovery unit**

A03.3.6.1. An efficient oil separator shall be included to remove oil from the refrigerant and there shall be suitable heat exchanger for oil separation, if required. Compressor shall be fully field serviceable with full acoustical alteration as per AHRI standard (Latest) and early serviceable type. Discharge oil separation shall be accomplished external to the compressor casing, oil separator and return system. Seal shall be designed to ensure that oil is adequately returned to the compressor and does not collect in the heat exchangers.

A03.3.7 **Control panel**

A03.3.7.1. The unit shall be complete with a Microprocessor Based Interactive Control Panel having multi colour display mounted directly on the unit and prewired with all operating and safety controls. Control panel shall be BMS compatible. Manufactuer's best available control panel as per their published catalogue shall be slected by MRTS authority during approval.

A03.3.7.2. Following specifications of control panel are mentioned for guidance purpose.The control panel shall have the following extended capabilities:

1. Remote indication of:
    - Chiller operating status
    - Shutdown codes
    - Key operating parameters including but not limited to:
        – Entering and leaving chilled water temperatures
        – Entering and leaving condenser water temperatures
        – Oil feed and sump temperatures
        – Oil pump discharge and oil differential pressure
        – Motors amps and amps as a percent of rated load amps
        – Hours of operation and number of starts, time of last start and stop
        – Fault history for last 8 failures
        - Self-diagnostics
2. Programming capabilities of:
    - Leaving chilled water temperature
    - Reset of chilled water temperature from:
        – Return chilled water temperature (to maintain constant return chilled water temperature)

  - Reset of supply water temperature between +8°C to +12°C
  - Load on chiller
- Power demand limit
- Lead-lag operation and control

3. The control panel should include but not to be limited to the items listed below:
   - Start/Stop switch (for both local/remote operation) and micro-processor module for capacity control system with overload limit control point adjustment, oil pump and purge unit controls, etc
   - Indicating lights
   - Suction, oil and discharge pressure indications
   - Necessary motor protection devices
   - Other time delays, relays, etc as required
4. As a minimum the following safeties shall be incorporated in the control panel:
   - High and low discharge pressure
   - High discharge temperature
   - Chilled or condenser water pumps failure
   - High or low oil feed temperature
   - Low oil differential pressure
   - High motor temperature, low motor current
   - Starter fault

A03.3.7.3. The display shall have a minimum of 160-characters liquid crystal having multi colour display and be backlit with a light emitting diode. Messages shall be in plain English. Coded two or three characters displays are not acceptable.

A03.3.7.4. A time clock shall be incorporated to allow daily time starts and stops

A03.3.7.5. The control system shall have automatic restart after a power failure and not require a battery backup for memory continuity.

A03.3.7.6. The microprocessor shall be capable of communicating to other units or a PC using a twisted pair communication interface RS-232 or RS422/485 or with a 9600-baud modem. The protocol should be BAC-NET/MOD BUS compatible. In case of any translator being required for communication between the chiller panel & BMS the same would be required to be provided by the ECS contractor.

A03.3.8 Refrigerant piping

A03.3.8.1. Necessary steel/copper refrigerant pipe lines as per approved manufacturer’s standard of heavy class shall be provided for the flow of suction and hot gases and liquid refrigerant. All control cables of the Chiller should be provided in the metal conduits.

A03.3.8.2. The pipe lines shall be insulated, as required.

A03.3.8.3. The chilling units shall be delivered with pre-charged refrigerant from the manufacturing premisses. The refrigerant shall not be charged at site.

A03.3.9 Lubrication system

A03.3.9.1. The lubrication system shall be complete with accessories such as oil chiller with thermostatic control, oil heaters, oil strainer, relief valve etc.

A03.3.9.2. Necessary pipe lines for lubricants and Cooling system with valves, shall be included.

A03.3.10 Accessories

A03.3.10.1. Each unit shall include the following as part of unit price:

- Spring type / rubber pads vibration isolators to eliminate transmission of vibrations upto 90%.
- Full charge of refrigerant gas and required quantity of lubrication oil.
- Other valves as required for cleaning of condenser and draining of water.
- KW meter with functional display.

A03.3.10.2. Each unit shall have the following item priced separately:

- Water flow switches at the outlet of the condenser and the chiller
- Stem type thermometers and dial type water pressure gauges at the inlet and outlet of the condenser and the chiller
- Suitable size motorised butterfly valves at the outlet of the condenser and chiller
- Suitable size balancing valve at the inlet of condenser and chiller
- Automatic air vent at the inlet and outlet of chiller

A03.3.10.3. Each unit shall include, but not to be limited to, all the items listed in the foregoing paragraphs or in the "schedule of equipment" and drawings for this project. In addition all such items, as may required, shall be included whether specifically mentioned or not, if considered or found necessary to fulfil the intent and meaning for the purpose of maintaining design operations under all extreme weather conditions.

A03.3.10.4. All exposed surfaces and insulation shall be painted using the Manufacturer's standard paint system and colours.

A03.3.11 Soft Starter for compressor motor

A03.3.11.1. The starter for the motor shall be automatic Soft type with tappings to limit starting current, within 2.5 times the full load current.

A03.3.11.2. Unit mounted pre wired & pre tested with factory settings soft Starters include all necessary safety devices i.e. Overload relays, under voltage release and single phase preventing device.

A03.3.11.3. The motor starter shall be factory mounted and fully wired and factory tested during the run test of the unit

A03.3.11.4. The starter shall have a metal nameplate showing Manufacturer's identifying numbers, serial number, maximum full load amps, and maximum overload trip setting. Starter shall have affixed to the inside of the door complete, as built, wiring scheme showing all accessory items.

A03.3.12 Type of refrigerant

A03.3.12.1. Units using R 134a/R-410A refrigerant shall be offered.

A03.3.13 Limitation

A03.3.13.1. The water velocity in the condenser and the chiller shall not exceed 3m/s.

A03.3.14 Execution

A03.3.14.1. The complete water-chilling unit shall be mounted on a R.C.C. foundation. Necessary foundation bolts, nuts, levelling shims etc., required for mounting of the unit shall be provided by the contractor.

A03.3.14.2. Contractor shall install chillers, including components and controls required for chiller operation, in accordance with chiller Manufacturer's written instruction and recommendations. Chillers shall be installed on an equipment pad with vibration isolators.

A03.3.14.3. Contractor shall field insulate all cold surface (not factory insulated) to prevent condensation.

A03.3.14.4. Contractor shall paint damaged and abraded factory finish with touch-up paint matching factory finish.

A03.3.14.5. All controls and switchgear shall be tested for proper functioning and set of design values.

A03.3.14.6. On completion of installation and tests the Water Chilling unit shall be tested for performance. The capacity in kcal/hr (tons) shall be calculated from measurements of temperature difference and flow rate of water in condenser and water in chiller. The power consumption shall be checked from current measurement of the motor. All calculated and checked results shall match the specified data.

A03.3.14.7. The Contractor shall provide all instruments and personnel for tests.

A03.3.14.8. Machines, which operate below atmospheric pressure, shall be pressure tested after shipment and prior to refrigerant charging without exceeding test pressure recommended by the Manufacturer. Machine shipped precharged need not comply with this requirement unless the factory precharge or holding charge is lost during shipment or prior to start-up, in which case, Contractor shall test as indicated.

A03.3.14.9. Contractor shall perform all tests and start-up in such a manner as not to introduce moisture into the machine.

- Factory Tests
- Nitrogen Charging
- Refrigerant leak detection device

A03.3.1.3. Centrifugal Water Chillers

A03.3.1.1 Description: Factory-assembled and -tested water chiller complete with single or multiple compressor(s), evaporator, condenser, controls, interconnecting unit piping and wiring, indicated accessories, and mounting frame.

A03.3.1.2 Fabricate water chiller mounting frame and attachment to the pressure vessel with reinforcement strong enough to resist water chiller movement during a seismic event when the water chiller mounting frame is anchored to the building structure.

A03.3.1.3 Water Chiller Characteristics and Capacities: to be design to suit the scheduled performance requirements.

A03.3.2. Centrifugal Compressors

A03.3.2.1 Description: Non positive displacement with gear-drive, open, direct-drive, hermetically sealed or direct-drive, semi-hermetically sealed motor.

- Casing: Cast iron, precision ground. Casing design shall ensure that major wearing parts, bearings thrust bearings are accessible for maintenance and replacement. Condensed liquid refrigerant shall be injected in to the compressor discharge to reduce discharge gas temperature and to reduce sound level of the compressor
- Impeller: High strength, cast-aluminum alloy on carbon- or forged-steel shaft; statically and dynamically balanced.
- The motor shall be of minimum efficiency class IE2.

A03.3.2.2 Capacity Control: Variable-inlet guide-vane assembly for stable operation that is free of surge, cavitation, or vibration throughout throttling range from 100 to 15 percent of full load even at constant condenser water temp. Oil Lubrication System: Positive-displacement submersible pump with heater, oil filter, and sight glass.The oil pump shall operate prior to start-up, during compressor operation and during coastdown. Compressor shall have an auxiliary reservoir to provide lubrication during coastdown in the event of a power failure.

A03.3.2.4 Refrigerant: HFC 134a/ R-410Aand Oil: Manufacturer's standard.

A03.3.2.5 Refrigerant Compatibility: Seals, 0-rings, motor windings, and internal water chiller parts exposed to refrigerants shall be fully compatible with refrigerants, and pressure components shall be rated for refrigerant pressures.

A03.3.3.7. Compressor motor shall be provided with overcurrent, single phasing and phase reversal protection.

A03.3.3 Heat Exchangers

A03.3.3.1 Evaporator:

A03.3.3.1.1 Description: Shell-and-tube design, ASME labeled.

A03.3.3.1.2 Shell Material: Carbon steel.

A03.3.3.1.3 Tube Construction: Individually replaceable, expanded into tube sheets.

- Material: Copper.
- Minimum Size: 19mm OD; 0.635 mm wall thickness.
- Internal Finish: Enhanced.

A03.3.3.1.3 Not used

A03.3.3.1.3 Pass : Even

A03.3.3.1.3 All cold parts of the evaporator shall be insulated.

A03.3.3.2 Condenser:

A03.3.3.2.1 Description: Shell-and-tube design, ASME labeled.

A03.3.3.2.2 Shell Material: Carbon steel.

A03.3.3.2.4 Tube Construction: Externally enhanced and individually replaceable, expanded into tube sheets.

- Material: Copper.
- Minimum Size: 19mm OD; 0.635 mm wall thickness.
- Internal Finish: Smooth or enhanced.

A03.3.3.2.4 Water Box: Hinged Marine water box, with design working pressure of as per manufacturer standard, and having Bolted/flanged water-nozzle connections with a thermistor-type temperature sensor factory installed in each nozzle.

A03.3.3.2.4 Pass : Even

A03.3.4 Insulation

A03.3.4.1 Cold Surfaces: Closed-cell, flexible elastomeric, thermal insulation complying with ASTM C 534, Type II, for sheet materials.

A03.3.4.1.1 Thickness: 19mm.

A03.3.4.1.2 Adhesive: As recommended by insulation manufacturer.

A03.3.5 Factory applied insulation over entire surfaces of water chiller components.

- Apply adhesive to 100 percent of insulation contact surface.
- Seal seams and joints.
- After adhesive has fully cured, apply two coats of protective coating to insulation.

A03.3.5 Accessories

A3.3.5.1 Pressure Relief Valve: Single- or multiple-reseating-type, spring-loaded relief valve.

A3.3.5.2 Purge System: Factory mounted, air, water, or refrigerant cooled; with operating controls, piping, elapsed-time meter, and refrigerant service valves to isolate the purge unit from the chilling unit.

A3.3.5.3 Each unit shall include the following as part of unit price:

- Spring type / rubber pads vibration isolators to eliminate transmission of vibrations upto 90%.
- Full charge of refrigerant gas and required quantity of lubrication oil.
- Other valves as required for cleaning of condenser and draining of water.

- KW meter with functional display.

A3.3.5.4 Each unit shall have the following item priced separately:

- Water flow switches at the outlet of the condenser and the chiller
- Stem type thermometers and dial type water pressure gauges at the inlet and outlet of the condenser and the chiller
- Suitable size motorised butterfly valves at the outlet of the condenser and chiller
- Suitable size balancing valve at the inlet of condenser and chiller
- Automatic air vent at the inlet and outlet of chiller

A3.3.5.5 Each unit shall include, but not to be limited to, all the items listed in the foregoing paragraphs or in the "schedule of equipment" and drawings for this project. In addition all such items, as may required, shall be included whether specifically mentioned or not, if considered or found necessary to fulfil the intent and meaning for the purpose of maintaining design operations under all extreme weather conditions.

A3.3.5.6 All exposed surfaces and insulation shall be painted using the Manufacturer's standard paint system and colours.

A03.3.6 Controls

General: The chiller shall be controlled by a stand-alone microprocessor based control center. The chiller control panel shall provide control of chiller operation and monitoring of chiller sensors, actuators, relays and switches.

Manufactuer's best available control panel as per their published catalogue shall be slected by MRTS authority during approval. The control panel have BMS compatibility. Following specifications of control panel are mentioned for guidance purpose.

A03.3.6 **Control panel:** The control panel shall include a 10.4 in. diagonal color liquid crystal display (LCD) surrounded by "soft " keys which are redefined based on the screen displayed at that time. This shall be mounted in the middle of a keypad interface and installed in a locked enclosure. The screen shall detail all operations and parameters, using a graphical representation of the chiller and its major components. Panel verbiage shall be available in other languages as an option with English always available. Data shall be displayed in either English or Metric units. Smart Freeze Point Protection shall run the chiller at 36°F leaving chilled water temperature, and not have nuisance trips on low water temperature. The sophisticated program and sensor shall monitor the chiller water temperature to prevent freeze up. When needed Hot Gas Bypass is available as an option. The panel shall display countdown timer messages so the operator knows when functions are starting and stopping. Every programmable point shall have a pop-up screen with the allowable ranges, so that the chiller can not be programmed to operate outside of its design limits.

The chiller control panel shall also provide:

- System operating information including:

a. return and leaving chilled water temperature

b. return and leaving condenser water temperature
c. evaporator and condenser saturation temperature
d. differential oil pressure
e. percent motor current
f. evaporator and condenser saturation temperature
g. compressor discharge temperature
h. oil reservoir temperature
i. compressor thrust bearing positioning and oil temperature
j. operating hours
k. number of compressor starts

- Digital programming of setpoints through the universal keypad including:

a. leaving chilled water temperature
b. percent current limit
c. pull-down demand limiting
d. six-week schedule for starting and stopping the chiller, pumps and tower
e. remote reset temperature range

- Status messages indicating:

a. system ready to start
b. system running
c. system coastdown
d. system safety shutdown-manual restart
e. system cycling shutdown-auto restart
f. system prelube
g. start inhibit

- The text displayed within the system status and system details field shall be displayed as a color codedmessage to indicate severity: red for safety fault, orange for cycling faults, yellow for warnings, and green for normal messages.

- Safety shutdowns enunciated through the display and the status bar, and consist of system status, system details, day, time, cause of shutdown, and type of restart required. Safety shutdowns with a fixed speed drive shall include:

a. evaporator – low pressure
b. evaporator – transducer or leaving liquid probe
c. evaporator – transducer or temperature sensor
d. condenser – high pressure contacts open
e. condenser – high pressure
f. condenser – pressure transducer out of range
g. auxiliary safety – contacts closed
h. discharge – high temperature
i. discharge – low temperature
j. oil – high temperature
k. oil – low differential pressure
l. oil – high differential pressure
m. oil – sump pressure transducer out of range
n. oil – differential pressure calibration
o. oil – variable speed pump – pressure setpoint not achieved
p. control panel – power failure
q. motor or starter – current imbalance

r. thrust bearing – proximity probe clearance
s. thrust bearing - proximity probe out – of – range
t. thrust bearing – high oil temperature
u. thrust bearing – oil temperature sensor
v. watchdog – software reboot

- Cycling shutdowns enunciated through the display and the status bar, and consists of system status, system details, day, time, cause of shutdown, and type of restart required. Cycling shutdowns with a fixed speed drive shall include:

a. multiunit cycling – contacts open
b. system cycling - contacts open
c. oil - low temperature differential
d. oil – low temperature
e. control panel - power failure
f. leaving chilled liquid - low temperature
g. leaving chilled liquid - flow switch open
h. motor controller – contacts open
i. motor controller – loss of current
j. power fault
k. control panel - schedule
l. starter – low supply line voltage
m. starter – low supply line voltage
n. proximity probe – low supply voltage
o. oil - variable speed pump - drive contacts open

- Security access to prevent unauthorized change of setpoints, to allow local or remote control of the chiller, and to allow manual operation of the prerotation vanes and oil pump. Access shall be through ID andpassword recognition, which is defined by three different levels of user competence: view, operator, and service.

- Trending data with the ability to customize points of once every second to once every hour. The panelshall trend up to 6 different parameters from a list of over 140, without the need of an external monitoringsystem.

- The operating program stored in non-volatile memory (EPROM) to eliminate reprogramming the chiller dueto AC power failure or battery discharge. Programmed setpoints shall be retained in lithium battery-backedRTC memory for a minimum of 11 years with power removed from the system.

- A fused connection through a transformer in the compressor motor starter to provide individual over-current protected power for all controls.

- A numbered terminal strip for all required field interlock wiring.

An RS-232 port to output all system operating data, shutdown / cycling message, and a record of the last

- Cycling or safety shutdowns to a field-supplied printer. Data logs to a printer at a set programmable interval. This data can be preprogrammed to print from 1minute to 1day.

- The capability to interface with a building automation system (Modbus protocol) to provide:

a. remote chiller start and stop
b. remote leaving chiller liquid temperature adjust
c. remote current limit setpoint adjust
d. remote ready to start contacts
e. safety shutdown contacts
f. cycling shutdown contacts
g. run contacts

A03.3.6.1 Control Panel: Stand-alone, microprocessor based. Microprocessor based chiller control with network connection to Building Management System (BMS) utilizing the same protocol as the BMS.

A03.3.6.2 Enclosure: Unit-mounted, NEMA 250, Type 1 enclosure, hinged or lockable; factory wired with a single-point power connection and a separate control circuit.

A03.3.6.6 Status Display: Multiple-character liquid-crystal display or light-emitting diodes and keypad. Display the following conditions:

- Date and time.
- Operating or alarm status.
- Operating hours.
- Outside-air temperature if required for chilled-water reset.
- Temperature and pressure operating set points.
- Entering and leaving temperatures of chilled water and condenser water.
- Refrigerant pressures in evaporator and condenser.
- Saturation temperature in evaporator and condenser.
- Oil temperature and pressure.
- Percent of maximum motor amperage.
- Current-limit set point.
- Number of compressor starts.
- Purge suction temperature if purge system is provided.
- Purge elapsed time if purge system is provided.

A03.3.6.6 Control Functions:

- Manual or automatic startup and shutdown time schedule.
- Entering and leaving chilled-water temperatures, control set points, and motor load limit.
- Current limit and demand limit.
- Condenser-water temperature.
- External water chiller emergency stop.
- Eaporator and condenser saturation temperature
- Differential oil pressure
- Percent motor current
- Evaporator and condenser saturation temperature
- Compressor discharge temperature
- Oil reservoir temperature
- Compressor thrust bearing positioning and oil temperature
- Operating hours
- Number of compressor starts

A03.3.6.6 Manually Reset Safety Controls: The following conditions shall shut down water chiller and require manual reset:

- Low evaporator pressure; high condenser pressure.
- Low chilled-water temperature.
- Low oil differential pressure.
- High or low oil pressure.
- High oil temperature.
- High compressor-discharge temperature.
- Loss of chilled- or condenser-water flow.
- Electrical overload.
- Sensor- or detection-circuit fault.
- Processor communication loss.
- Starter fault.
- Extended compressor surge.
- Excessive air-leakage detection.

A03.3.6.6 BMS Interface: Factory-installed hardware and software to enable the BMS to monitor chiller status and control chiller functions, as indicated.

motors

A03.3.7.1 Comply with requirements in specification for Motors for open-drive motors.

A03.3.7.2 Open-drive motors shall have flanged or flexible coupling suitable for direct connection to compressor.

A03.3.10 Source Quality Control

A03.3.10.1 Rate water chillers according to AHRI 550/590, "Water Chilling Packages Using the Vapor Compression Cycle." Stamp with AHRI label.

A03.3.10.2 Factory test heat exchangers hydrostatically at 1.50 times the design pressure.

A03.3.10.3 Factory test and inspect evaporator and water cooled-condenser according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1. Stamp with ASME label.

A03.3.10.4 Factory test and inspect water boxes at 150 percent of working pressure.

A03.3.10.5 Rate sound power level according to AHRI 575 procedure.

A03.3.10.6 Allow Employer access to places where water chillers are being source quality-control tested. Notify Employer 14 days in advance of testing.

A03.3.11 Execution

A03.3.11.1 Examination

A03.3.11.1.1 Before water chiller installation, examine roughing-in for concrete equipment bases, anchor-bolt sizes and locations, piping, and electrical to verify actual locations, sizes, and other conditions affecting water chiller performance, maintenance, and operations.

A03.3.11.1.1.1 Final water chiller locations indicated on Drawings are approximate. Determine exact locations before roughing-in for piping and electrical connections.

A03.3.11.1.2 Proceed with installation only after unsatisfactory conditions have been corrected.

A03.3.11.2 Chiller Installation

A03.3.11.2.1 Install water chillers on concrete base.

A03.3.11.2.2 Concrete Bases: Anchor chiller mounting frame to concrete base.

A03.3.11.2.2.1 Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 450mm centers around the full perimeter of concrete base.

A03.3.11.2.2.2 For supported equipment, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.

A03.3.11.2.2.3 Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.

A03.3.11.2.2.4 Install anchor bolts to elevations required for proper attachment to supported equipment.

A03.3.11.2.2.5 Cast-in-place concrete materials and placement requirements are specified in Division 3.

A03.3.11.2.3 Vibration Isolation: Rubber pads with a minimum deflection of 6.35mm. Vibration isolation devices and installation requirements are specified in project specification for "Mechanical Vibration Controls" (doc no 25045-13-3PS-15241).

A03.3.11.2.4 Maintain manufacturer's recommended clearances for service and maintenance.

A03.3.11.2.5 Charge water chiller with refrigerant, if not factory charged.

A03.3.11.2.6 Install separate devices furnished by manufacturer.

A03.3.11.3 Connections

A03.3.11.3.1 Provide Chilled and condenser-water piping end connections as flanged type as per ASME standard.

A03.3.11.3.2 Install piping adjacent to water chillers to allow service and maintenance.

A03.3.11.3.3 Refrigerant Pressure Relief Valve Connections: Extend vent piping to the outside without valves or restrictions.

A03.3.11.3.4 Ground water chillers according to electrical requirements for Electrical Earthing and Bonding.

A03.3.11.3.5 Tighten electrical connectors and terminals according to manufacturer's published torque-tightening values. If manufacturer's torque values are not indicated, use those specified in UL 486A and UL 486B.

A03.3.11.4 Start up service

A03.3.11.4.1 Engage a factory-authorized service representative to perform startup service.

A03.3.11.4.2 Inspect field-assembled components, equipment installation, and piping and electrical connections for proper assemblies, installations, and connections.

A03.3.11.4.3 Complete installation and startup checks according to manufacturer's written instructions and perform the following:

A03.3.11.4.3.1 Verify that refrigerant charge is sufficient and water chiller has been leak tested.

A03.3.11.4.3.2 Verify that pumps are installed and functional.

A03.3.11.4.3.3 Verify that thermometers and gages are installed.

A03.3.11.4.3.4 Operate water chiller for run-in period according to manufacturer's written instructions.

A03.3.11.4.3.5 Check bearing lubrication and oil levels.

A03.3.11.4.3.6 Verify that refrigerant pressure relief is vented outside.

A03.3.11.4.3.7 Verify proper motor rotation.

A03.3.11.4.3.8 Verify static deflection of vibration isolators, including deflection during water chiller startup and shutdown.

A03.3.11.4.3.9 Verify and record performance of chilled- and condenser-water flow and lowtemperature interlocks.

A03.3.11.4.3.10 Verify and record performance of water chiller protection devices.

A03.3.11.4.3.11 Test and adjust controls and safeties. Replace damaged or malfunctioning controls and equipment.

A03.3.12.1 Prepare a written startup report that records results of tests and inspections.

A03.3.11.4.5 Occupancy Adjustments: When requested within 12 months of date of Final Acceptance, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to two visits to site outside normal occupancy hours for this purpose.

A03.3.11.5. Demonstration

A03.3.11.5.1 Engage a factory-authorized service representative to train Employer's maintenance personnel to adjust, operate, and maintain water chillers

A03.3.12 Compressor Motor Starter

A03.3.11.5. The starter for the motor shall be automatic Soft type with tappings to limit starting current, within 2.5 times the full load current.

A03.3.11.6. Unit mounted pre wired & pre tested with factory settings soft Starters include all necessary safety devices i.e. Overload relays, under voltage release and single phase preventing device.

A03.3.11.7. The motor starter shall be factory mounted and fully wired and factory tested during the run test of the unit

The starter shall have a metal nameplate showing Manufacturer's identifying numbers, serial number, maximum full load amps, and maximum overload trip setting. Starter shall have affixed to the inside of the door complete, as built, wiring scheme showing all accessory items

A03.3.12.1 Solid state starter

Manufacturer will furnish a reduced-voltage, Solid State Starter, factory-mounted on the centrifugal liquid chilling unit. The starter enclosure will be NEMA 1 and will be of modular construction with complete access to all parts without disturbing the refrigerant circuit. Power wiring from the starter to the compressor motor and control wiring from the starter to the chiller control panel will be completed at the factory. The starter will be tested and the design starting current and overload settings will be adjusted at the factory. The starter will provide, through the use of six silicon-controlled rectifiers (2 per phase) a smooth acceleration of the motor without current transitions or transients.

The following protective devices will be factory mounted and wired to the starter:

3-leg sensing electronic overloads with indicating lights and reset button – will shut unit down if current exceeds 105% of FLA to protect the motor windings.
Phase rotation protection circuit and indicating light – will deny start-up when detecting incorrect power wiring phase sequence to the starter which could cause reverse motor rotation and damage the equipment.
Single-phase failure protection circuit and indicating light – will insure against motor burnout by shutting the unit down if power loss occurs in any of the incoming lines during start-up.
High temperature safety protection system with indicating light and reset button – thermistors embedded on heat sinks will shut the unit down if the SCR temperature exceeds acceptable limits.
Hinged access door with lock and keys – will prevent tampering by unauthorized personnel.
High and low line voltage protection.

The following convenience items will be factory mounted and wired to the starter:

Auxiliary 1-1/2 KVA transformer – will eliminate the need for running separate 115V-1ph-50/60 Hz power source wiring to the OptiView Control Panel.
Digital Elapsed Time Meter – will easily keep track of operating hours to gauge regular maintenance and inspection requirements.
Power Fault Protection – momentary power interruption protection detects power interruptions within ¾ line cycle and will interrupt power to the compressor motor within 4 line cycles.
Electrical lugs – these tin-plated lugs will provide easy connection to incoming copper power lines.
3-phase digital ammeter and digital voltmeter readout via control panel – will easily crosscheck design current and voltage limitations against supply characteristics. Meter readings (selected in accordance with starter selection) amps: 0-750, 0-1500, 0-2800, 0-3500 volts: 0-300, 0-700.

KW Meter - The unit's input power consumption will be measured and displayed digitally via the unit's control panel. The KW meter accuracy is typically +/- 3% of reading. KW meter scale is 0 - 1900 KW .

KWh Meter – The unit's cumulative input power consumption is measured and displayed digitally via the unit's control panel. The KWh meter is resetable and it's accuracy is typically +/- 3% of reading. KWh meter scale is 0 – 999,999 kWh.

Ammeter – Simultaneous three-phase true RMS digital readout via the unit control panel. Three current transformers provide isolated sensing. The ammeter accuracy is typically +/- 3% of readming. Ammeter scale is 0 - 1640 A RMS .

Voltmeter – Simultaneous three-phase true RMS digital readout via the unit control panel. The voltmeter accuracy is typically +/- 3% of reading. Voltmeter scale is 0 – 670 VAC.

Elapsed Time Meter – Digital readout of the unit's elapsed running time (0 – 876,600 hours, resetable) is displayed via the unit control panel.

DATA SHEET FOR WATER COOLED CHILLER - SCREW COMPRESSOR	
Unit Type	Water Cooled Rotary Screw Chiller
Reference Code / Standard	AHRI 550/590(latest), ASME sec VIII Div 1, ANSI B 31.5
Tag No	Tag No To Be Marked On Chiller With Black Letter. SS Tag To Be Firmly Attached
Unit Capacity	As per BOQ
Evaporator water flow rate LPS	2 USGPM/TR
Condenser water flow rate LPS	4 USGPM/TR
Total Quantity	As per BOQ
COP @ AHRI Conditions	6.1 minimum
Maximum ikW @ AHRI	0.576 KW / TR
Refrigerant	R – 134a/ R-410A
Noise Criteria	85 dB at 1m distance
Differential Pressure Switch	One Each For Condenser And Chiller
Sight Glass	Liquid level sight glass in Evaporator
Vibration Isolators	Spring Type Vibration Isolator./Rubber pad type vibration isolator
Unit Consisting Of	1. Compressor 2. Chiller 3. Condenser 4. Microprocessor Based Control Panel 5. Soft Starter
Oil Separator	Hi-efficiency oil separator.
Compressor	
Type	Rotary Screw –Twin Rotor Type/ Semi Hermetically Sealed
Test Pressure	as per manufacturers standard
Working Pressure	as per manufacturers standard
Housing	As per manufactures standard
Impeller	Fully Shrouded
Bearings	As per manufacturing standard
Shaft Seal	N/A
Refrigerants' Valves	Isolation Valves to be provided.
Capacity Control	step less capacity control through slide valve from 100% to 20% of full load at constant condenser inlet temperature of 32.2 degC.
Oil Filter	3 micron absolute oil filter with isolation valve.
Condenser	
Type	Shell And Tube
No Of Pass	Even Passes (Minimum Two)
Fouling Factor	0.000176 Sq.Mtr. °C / W
Water	

Inlet Temp.		30.0°C
Outlet Temp.		34.4°C
	Velocity	3 m/s (Max)
	Pressure Drop	90 kPa (Max)
Shell		
Material		Steel
Test Pressure (pneumatic)		as per manufacturer standard.
Tube		
Material		Copper Or Copper Alloy (12mm OD, 24 Gauge)
Test Pressure (pneumatic)		As per manufacturer's quality procedures
Chiller		
Type		Flooded
No Of Pass		Even Passes (Minimum Two)
Water Velocity		3 m/s (Max)
Water		
Inlet Temp.		15 °C
Outlet Temp		8 °C
Fouling Factor		0.000088 Sq.Mtr.° C / W
Pressure drop		80 kPa (Max)
Shell		
Material		Steel
Test Pressure (pneumatic)		As per manufacturer's quality procedures
Tube		
Material		Copper Or Copper Alloy (19 mm OD, 24 Gauge)
Test Pressure (pneumatic)		as per manufacturer standard
Control Panel		
Type		Advanced Digital Micro Processor Based, Programmable, BMS interfaced
Fault Indication		Red LED Display On screen
Current Measurement		Digital Display of each Phase Amp.
Chilled water temp ^{0}C		Entering And Leaving Temperature Status
Condenser water temp ^{0}C		Entering And Leaving Temperature Status
Control Panel		
Refrigerant Pressure Kg/ Cm^2		Evaporator and Condenser Pressure Status
Oil Pressure		Measuring Device To be provided
System Voltage		Digital Display on Panel
Compressor Motor Amp		Digital Display on Graphical Panel
Compressor		Indication On / Off Status

Panel	
Material	M.S Heavy Gauge
Door	Control Interlock
Paint	Anti Corrosive – Powder Coating Duly Treated For Corrosion
System Protection	
Anti-Fouling Device (AFD)	At the Condenser Inlet of Chillers
Low Pressure	Alarm And Tripping
High Discharge	Alarm And Tripping
Freeze Protection	Alarm And Tripping
High Oil Temp	Alarm And Tripping
Lubrication Failure	Alarm And Tripping
Low Oil Level	Indication
Low Differential Pressure In Condenser	Alarm And Tripping
Low Differential Pressure In Chiller	Alarm And Tripping
Compressor Failure	Alarm And Tripping
Anti Recycle	Tripping
Winding Temp. Sensor	Tripping

Notes:

1. Chillers shall be as per DMRC specifications. Any deviations to the specifications should be pointed out at tendering stage.
2. Condenser shall be provided with marine boxes made of steel or cast iron for ease of cleaning.
3. Chiller Motor starter shall be Soft starter without transient type.
4. Above data is not by way of limitation. Whatever is required for making the unit complete to meet the intent of specifications shall be deemed to have been included in the scope of work.
5. Flexible Connections at chiller and condenser shall be provided.
6. Chillers shall be equipped with the antifouling devices.
7. Over current, phase reversal, single phasing protections and KW meter shall be provided.
8. Refrigerant sensor shall be installed.
9. Performance rating.
10. The unit shall be selected for the lowest operating power consumption and noise level. Computer selected capacity rating and power consumption with operating points clearly indicated, shall be submitted with the tender as per technical data specified in the tender on full and partial load and shall be verified at the time of testing and commissioning of the installation. The gear losses should be included in the IKW/TR figures indicated by the bidders
11. Capacity and power consumption shall be computed from the measurements of incoming voltage, input current, temperature (inlet & outlet) and water flow rate. Necessary provision shall be kept for providing flow meter and transducers required for computing capacity.
12. The supplier has to confirm that the IKW/TR data for the chilling unit submitted by

him has been selected at the specified operating parameters and at constant condenser entering water temperature.

13. Also the machine shall be rated for actual capacity at specified conditions.
14. Only AHRI / Eurovent certified chilling machine shall be acceptable and the computer performance sheet. duly certified as per AHRI / Eurovent shall be submitted along with the technical submittal.
15. The IKW/TR and NPLV values at the specified operating parameters and at constant condenser entering water temperature, rated in accordance with AHRI-550-590/98, shall be submitted with the tender. The values committed shall be verified at the time of installation shall be indicated at the time of submission offer and shall be supervised by the supplier as recommended by the chilling unit manufacturer.

DATA SHEET FOR MAG BEARING CENTRIFUGAL CHILLERS	
Unit Type	Water Cooled Chiller
Reference Code / Standard	ARI 550/590(latest), ASME sec VIII Div 1, ANSI B 31.5
Tag No	Tag No To Be Marked On Chiller With Black Letter. SS Tag To Be Firmly Attached
Unit Capacity	as per BOQ ±5%
Evaporator water flow rate LPS	As per BOQ
Condenser water flow rate LPS	As per BOQ
Total Quantity	As per BOQ
COP @ ARI Conditions	6.3
Maximum ikW @ ARI	_
Maximum NPLV (kW/TR)	_
Refrigerant	R – 134a/ R-410A
Noise Criteria	85 dB at 1m distance
Differential Pressure Switch	One Each For Condenser And Chiller
Sight Glass	Liquid level sight glass in Evaporator
Vibration Isolators	Spring Type Vibration Isolator.
Unit Consisting Of	1. Compressor 2. Chiller with Hinged Marine water box 3. Condenser with Hinged Marine water box 4. Microprocessor Based Control Panel 5. Unit mounted VFD with active harmonic filter
Oil Separator	Hi-efficiency oil separator.
Compressor	
Type-Centrifugal	Mag bearing centrifugal compressor with permanent magnet motors, open drip proof and oil free lubrication
Test Pressure	25 Bar (G) (Hydro)
Working Pressure	17.57 Bar (G) (Max)
Housing	As per manufactures standard

Rotor	As per manufactures standard
Bearings	Magnetic
Shaft Seal	N/A
Refrigerants' Valves	Isolation Valves as per manufactures specifications to be provided.
Capacity Control	Step less capacity control thru VSD and inlet guide vanes from 100% to 15% of full load
Oil Filter	3 micron absolute oil filter with isolation valve.
Condenser	
Type	Shell And Tube
No Of Pass	Even Passes (Minimum Two)
Fouling Factor	0.000176 Sq.Mtr. °C / W
Water	
Inlet Temp.	30.0°C
Outlet Temp.	34.4°C
Velocity	3 m/s (Max)
Pressure Drop	80 kPa (Max)
Shell	
Material	Steel
Test Pressure (pneumatic)	24.5 Bar (min.)
Tube	
Material	Copper Or Copper Alloy
Test Pressure (pneumatic)	As per manufacturer's quality procedures
Chiller	
Type	Flooded
No Of Pass	Even Passes (Minimum Two)
Water Velocity	3 m/s (Max)
Water	
Inlet Temp.	15 °C
Outlet Temp	8 °C
Fouling Factor	0.000088 Sq.Mtr.° C / W
Pressure drop	80 kPa (Max)
Shell	
Material	Steel
Test Pressure (pneumatic)	As per manufacturer's quality procedures
Tube	
Material	Copper Or Copper Alloy (19 mm OD, 22 Gauge)
Test Pressure (pneumatic)	15.75 Bar

VFD	
Type of VFD	Unit Mounted
Type of Filter	Active Harmonic Filter
Power Factor	0.95
Control Panel	
Type	Advanced graphical Micro Processor Based Panel with Graphics, Programmable, BMS interfaced (MODBUS)
Fault Indication	Red LED Display On screen
Current Measurement	Digital Display of each Phase Amp.
Chilled water temp ^{0}C	Entering And Leaving Temperature Status
Condenser water temp ^{0}C	Entering And Leaving Temperature Status
Control Panel	
Refrigerant Pressure Kg/ Cm^2	Evaporator and Condenser Pressure Status
System Voltage	Digital Display on Panel
Compressor Motor Amp	Digital Display on Graphical Panel
Compressor	Indication On / Off Status
KW Meter	- The unit's input power consumption will be measured and displayed digitally via the unit's control panel.
KWh Meter	– The unit's cumulative input power consumption is measured and displayed digitally via the unit's control panel
Ammeter	– Simultaneous three-phase true RMS digital readout via the unit control panel. Three current transformers provide isolated sensing.
Voltmeter	– Simultaneous three-phase true RMS digital readout via the unit control panel. The voltmeter accuracy is typica
Panel	
Material	M.S Heavy Gauge
Door	Control Interlock
Paint	Anti Corrosive – Powder Coating Duly Treated For Corrosion
System Protection	
Anti-Fouling Device (AFD)	At the Condenser Inlet of Chillers
Low Pressure	Alarm And Tripping
High Discharge	Alarm And Tripping
Freeze Protection	Alarm And Tripping
High Oil Temp	Alarm And Tripping
Lubrication Failure	Alarm And Tripping
Low Oil Level	Indication
Low Differential Pressure In Condenser	Alarm And Tripping

Low Differential Pressure In Chiller	Alarm And Tripping
Compressor Failure	Alarm And Tripping
Anti Recycle	Tripping
Winding Temp. Sensor	Tripping

Notes:

1. Chillers shall be as per specifications. Any deviations to the specifications should be pointed out at tendering stage.
2. Condenser & cooler shall be provided with marine boxes made of steel or cast iron for ease of cleaning.
3. Chiller Motor starter shall be Soft starter without transient type.
4. Above data is not by way of limitation. Whatever is required for making the unit complete to meet the intent of specifications shall be deemed to have been included in the scope of work.
5. Flexible Connections at chiller and condenser shall be provided.
6. Over current, phase reversal, single phasing protections and KW meter shall be provided.
7. Refrigerant sensor shall be installed.
8. Performance rating.
9. The unit shall be selected for the lowest operating power consumption and noise level. Computer selected capacity rating and power consumption with operating points clearly indicated, shall be submitted with the tender as per technical data specified in the tender on full and partial load and shall be verified at the time of testing and commissioning of the installation. The gear losses should be included in the IKW/TR figures indicated by the bidders. As energy conservation is today's theme, it is expected from each bidder to offer highly energy efficient machines. Necessary credit of preference will be given on this account. Power consumption shall be computed from measurements of incoming voltage and input current.
10. Capacity and power consumption shall be computed from the measurements of incoming voltage, input current, temperature (inlet & outlet) and water flow rate. Necessary provision shall be kept for providing flow meter and transducers required for computing capacity.
11. The supplier has to confirm that the IKW/TR data for the chilling unit submitted by him has been selected at the specified operating parameters and at constant condenser entering water temperature.
12. Also the machine shall be rated for actual capacity at specified conditions.
13. Only ARI / Eurovent certified chilling machine shall be acceptable and the computer performance sheet. duly certified as per ARI / Eurovent shall be submitted along with the technical submittal.

Section A04: Air Cooled Chillers with Scroll Compressors

TABLE OF CONTENT

Section A04: Air Cooled Chillers with Scroll Compressors.

1.0 General

This section specifies the requirements for furnishing, installing and testing of Air Cooled Water chilling units with scroll compressors and appurtenances as specified herein, including but not limited to:

- Chiller package
- Charge of refrigerant and oil
- Controls and control connections
- Chilled water connections
- Condenser water connections

Air cooled chiller packages shall be factory assembled and tested for rated efficiency. Unit shall be delivered to site fully assembled, and charged with refrigerant and oil by the manufacturer.

2.0 Quality Control

2.1 Materials and workmanship shall be in accordance with the latest edition of the following standards and codes to the extent specified herein. The publications listed below form a part of these specifications to the extent referenced. The publications are referred to in the text by basic designation only.

2.2 ANSI/ASHRAE 15-1992 Safety code for mechanical refrigeration

2.3 Chiller shall be pressure-tested, evacuated and fully charged with refrigerant and Oil and shall be factory operational run tested with water flowing through the vessel.

2.4 Within 14 days after successful completion of all factory tests the Contractor shall submit the following:

a. Certified results for all factory tests conducted. All test data shall be bound in one report. The test report shall be indexed and cross-referenced in an easily understood manner.

b. Field test procedures.

3.0 Manufacturer's qualifications and experience

The Air cooled chilling units manufacturer shall show at least five years of continuous and current experience in the design, assembly and testing of such units. The Offered chillers shall be ARI/AHRI/Eurovent Certified.

4.0 Technical and Installation requirements

4.1. The water chilling machine shall be self contained type consisting of multiple scroll compressors, squirrel cage induction motor, air cooled condensers, chiller, refrigerant piping, wiring and automatic controls all mounted on a steel base frame forming a compact assembly. The water chilling machine shall be complete with full charge of Zero ODP Environmental friendly refrigerant R134a/ R410A and oil, vibration isolation pads and accessories, factory assembled and tested for rated capacity.

The IKW/TR for part load conditions of 25% and 50% under operating conditions shall be indicated.

Structure shall be factory assembled and constructed out of formed & powder coated galvanized steel panels.

4.2. Evaporator

Evaporator shall be shell and tube and multi-pass type or brazed plate type. The shell shall be of welded steel construction fitted with machined steel tube sheets on either ends. End water boxes shall be designed to provide adequate space for water movement such that there is no erosion of the tube ends. End box covers shall be removable, and allow easy access for cleaning the tubes.

The chillers shall either have internally finned copper tubes or tubes with other means for increasing heat transfer surface. The tube shall be supported in the shell by adequate, stiff supports to eliminate vibration and noise. The tube ends shall be mechanically bonded to the tube sheets to prevent leakage of refrigerant gas.

Tubes shall be of minimum 12mm O.D. The chiller shall be tested against leaks both on the shell and the waterside.
Chillers shall be complete with the following accessories:

a. Thermostatic expansion valves, pilot solenoid valves and filter drier.
b. Necessary drain valves and vent.
c. Anti freeze thermostat.
d. Other standard accessories, necessary for the equipment supplied.

The chiller shall be insulated with factory-installed insulation.

4.3. Condenser

Condensers shall be air cooled type of copper tube and aluminium fin construction. Copper tube dia shall be minimum 9.5mm. Condenser shall be manufactured to ASME codes for unfired pressure vessels and designed for refrigerant working pressure of 450 psig. Condenser shall be complete with provisions for refrigerant piping connections, shut off valves and any other standard accessory necessary with the equipment supplied. In case of twin compressor system two independent sets of condenser coils shall be incorporated. The condenser coils shall be arranged in staggered rows and shall be expanded into super slit aluminum fins to achieve superior efficiency. The fins shall have hydrophilic coating.

The condenser fans shall be propeller type, directly driven by a motor and positioned for vertical air discharge. The draw-through design provides uniform airflow over the entire condenser coil shall be, thus ensuring proper condensation throughout the coil. The condenser fan motors shall be of totally enclose squirrel case type with IP-55 type protection and shall be designed for outdoor operation in high ambient temperatures. They shall operate or 415 Volts, 3 Phase, 50 Hz supply.

4.4. Compressor

Chiller packages shall be provided with Hermetic Scroll compressors. The compressor shall be hermetically sealed having an integral cast iron frame & cast iron scrolls with a sight glass & an oil adjustment port. The compressor shall be internally lubricated with a highly refined, low foaming, mineral oil and should be provided with a crankcase heater.

4.5. Compressor Motor

The compressor motor should be hermetic, refrigerant gas cooled, efiiciency class IE-2 with inherent all phase protection and shall be suitable for 415 V, 3 phase, 50 cycles AC supply.

Motor shall be screen protected drip proof squirrel cage induction type, designed and guaranteed for continuous operation at name plate rating and motor to be suitable for the refrigerant being used. Temperature sensor shall be provided in motor winding to protect the motor for high temperature rise.

The starter for the motor shall be automatic Soft type with tappings to limit starting current, within 2.5 times the full load current.

Unit mounted pre-wired &pretested with factory settings Starters shall include all necessary safety devices i.e. Overload relays, under voltage release and single phase preventing device.

The motor starter shall be factory mounted and fully wired and factory tested during the run test of the unit
The starter shall have a metal nameplate showing Manufacturer’s identifying, serial number, maximum full load amps, and maximum overload trip setting. Starter shall have affixed to the inside of the door complete, as built, wiring scheme showing all accessory items.

4.6. Fans

The fans shall be dynamically and statically balanced, direct drive, corrosion resistant glass fiber reinforce composite blades molded into low noise, providing vertical air discharge from extended orifices for efficiency and low sound. Guards shall be made from heavy gauge, steel wire epoxy oven baked painting.

The Fan Motors shall be of efficiency class IE-2, direct driven, 3 phase, insulation class “F”. Totally Enclosed Fan Cooled (TEFC), rigid mounted, with double sealed, permanently lubricated, ball bearings.

4.7. Capacity Controls

The compressors shall have an automatic regulating capacity from 100% to 25%. In case of multiple compressors, sequencing of compressors shall be provided to allow the compressors to start at a time lag of 3-4 minutes.

4.8. Control Panels

The chiller shall be provided with a factory installed and wired micro processor based rain tight control panel. The control panel shall be provided with necessary TPN isolator for termination of incoming power cable. A contactor shall be included in the control centre for each compressor and a pair of fan motors.
The Control panel shall be BMS compatible. Manufactuer’s best available control panel as per their published catalogue shall be slected by MRTS authority during approval. Following specifications of control panel are mentioned for guidance purpose.

The control system shall automatically control the operation of the unit from the time the unit is started, through the operating period, until the unit is stopped. The internal components shall be arranged for easy access. The panel shall incorporate necessary interlocking between equipment as required. The motor control centre should include safety devices to protect the unit from mal functions. These controls should shut down the unit and signal the operator with their respective lights. The protective controls shall be as listed hereunder:
i. High condenser pressure cutout.
ii. Low oil pressure cutout.
iii. High oil temperature cutout.
iv. High discharge temperature cutout.
v. Solid state motor over current cutout.
vi. Solid state low evaporator temperature control.

The chiller shall be BMS compatible. The control panel shall incorporate hardware cards/control units for complete integration of chillers to building automation system.
The Software shall be stored in non-volatile memory, with programmed set-points retained in lithium battery backed real time clock (RTC) memory for minimum 5 years.

Liquid crystal display, descriptions in English, numeric data in English (or Metric) units.Sealed keypad with sections for Set points, Display/Print, Entry, Unit Options and clock, and On/Off Switch.

Programmable Set-points: Display language; chilled liquid temperature set point and range, remote reset temperature range, manual override for servicing, low and high ambient cutouts, number of compressors, low liquid temperature cutout, low suction pressure cutout, high discharge pressure cutout, anti-recycle timer (compressor start cycle time), and anti-coincident timer (delay compressor starts).

Display Data: Return and leaving liquid temperatures, low leaving liquid temperature cutout setting, low ambient temperature cutout setting, outdoor air temperature, English or metric data, suction pressure cutout setting, each system suction pressure discharge pressure (optional), liquid temperature reset via aBuilding Automation System (by others) via PWM input as standard or at a 4-20 milliamp or 0 10VDC input or contact closure with optional BAS interface, anti-coincident system start timer condition, compressor run status, no cooling load condition, day, date and time, daily start/stop times, holiday status, automatic or manual system lead/lag control, lead system definition, compressor starts/operating hours (each), status of hot gas valves, evaporator heater and fan operation, run permissive status, number of compressors running, liquid solenoid valve status, load and unload timer status, water pump status (optional).

System Safety: Shall cause individual compressor systems to perform auto shut down; for high discharge pressure, low suction pressure, high pressure switch, and motor protector. Compressor motor protector shall protect against damage due to high input current or thermal overload of windings.

Unit Safety: Shall be automatic reset and cause compressors to shut down if low ambient, low leaving chilled liquid temperature, under voltage, and flow switch operation. Contractor shall provide flow switch and wiring per chiller manufacturer requirements.

Alarm Contacts: Low ambient, low leaving chilled liquid temperature, low voltage, low battery, and (per compressor circuit): high discharge pressure, and low suction pressure.

Manufacturer shall provide any controls not listed above, necessary for automatic chiller operation. Mechanical Contractor shall provide field control wiring necessary to interface sensors to the chiller control system.

4.9. Power Panels

Rain tight, powder painted steel cabinets with hinged, latched, and gasket sealed outer doors. Provide main power connection (s), control power connections, compressor and fan motor start contactors, current overloads, and factory wiring.

Power supply shall enter unit at a single location, be 3-phase of scheduled voltage, and connect to unit terminal blocks.

Exposed compressor, control and fan motor power wiring shall be routed through liquid tight conduit.

4.10. Refrigerant Circuit

The unit shall consist of copper refrigerant piping, independent refrigerant circuits for multi compressor unit. Each refrigerant circuit shall include: liquid line shutoff valve with charging port, filter-drier, solenoid valve, sight glass with moisture indicator, thermostatic expansion valves, and flexible, closed-cell foam insulated suction line.

4.11. Installation

The air cooled chiller package housing compressor, chiller and condensers shall be mounted on structural foundation. The Contractor shall supply all necessary foundation bolts, nuts, washers, leveling screws, mounting frame or base plate, vibration isolation pads etc. After erection, the unit shall be properly leveled before grouting the foundation bolts and the levels should be shown to the Engineer's representative. All the equipment shall be thoroughly tested and checked for leaks.

The refrigeration filling shall be as per manufacture's recommendation. The system shall be vacuumed to within 7.6mm Hg Absolute and maintained for four hours. At the end of this period the pumps shall be stopped and vacuum maintained for twenty four hours without exceeding a vacuum drop of 2.5mm Hg Absolute. The Contractor shall certify that the vacuum was maintained as specified above. All safety controls, low and high refrigerant pressure controls, starter, overload trips shall be suitably set and record of all the setting shall be furnished to the employer.

5.0 Testing

Equipment capacity in tons of refrigeration shall be computed from the temperature readings and water flow measurements. Flow measurements shall be preferably through flow meters. Computed results should tally with the specified capacities and the power consumption should tally with the figures furnished with the submission. All instruments and services needed for the tests required for computation of capacity and power consumption shall be furnished by the Contractor themselves.

DATA SHEET FOR AIR COOLED CHILLER - SCROLL COMPRESSOR	
Unit Type	Air cooled scroll type
Reference Code / Standard	AHRI 550/590(latest), ASME sec VIII Div 1, ANSI B 31.5
Certification	AHRI / Eurovent
Tag No	Tag No To Be Marked On Chiller With Black Letter. SS Tag To Be Firmly Attached
Unit Capacity	As per BOQ
Evaporator water flow rate LPS	2 usgpm/ton minimum
Total Quantity	As per BOQ
COP @ AHRI Conditions	3.0 min
Maximum iKW @ AHRI	1.172 KW/TR
Maximum NPLV (kW/TR)	0.75
Refrigerant	R – 410A
Noise Criteria	As per AHRI
Differential Pressure Switch	One for Chiller
Vibration Isolators	Spring Type Vibration Isolator / Rubber pad type vibration isolator
Unit Consisting Of	1. Compressor 2. Chiller 3. Air cooled Condenser 4. Microprocessor Based Control Panel 5. Soft starter
Unit Protection	Welded wire-mesh guards must be mounted on the exterior of the unit. This prevents unauthorized access, yet provides free air flow. (Factory-mounted)
Compressor	
Type	Scroll Compressor
Test Pressure	as per manufacturer standard
Working Pressure	as per manufacturer standard
Housing	As per manufactures standard
Rotor	As per manufactures standard
Bearings	Anti Friction Type Cylindrical & Ball Bearings for Axial & Radial loads as per service life as per DMRC specifications.
Shaft Seal	N/A
Refrigerants' Valves	Isolation Valves as per manufactures specifications to be provided.
Capacity Control	Stepped capacity control
No of Refrigerant Circuits	2

Oil Filter	3 micron absolute oil filters with isolation valve.
Condenser	
Type	Air cooled, either Unimetal construction or epoxy coated (post coated dipped condenser coil at factory) cooper tubes with aluminium fins to avoid galvanic corrosion
Condenser fans	High efficiency (IE-2), direct drive, 6 pole, 3 phase, insulation class "F", current protected, Totally Enclosed Air-Over (TEAO), rigid mounted, with double sealed, permanently lubricated, ball bearings
Air Inlet Temp.	35 °C
Chiller	
Type	DX-Shell & Tube / Brazed Plate
Water	
Inlet Temp.	15 °C
Outlet Temp	8 °C
Fouling Factor	0.000088 Sq.Mtr.° C / W
Pressure drop	10 ft (max)
Test Pressure (pneumatic)	As per manufacturer's quality procedures
Tube	
Material	Copper Or Copper Alloy (19 mm OD, 22 Gauge)
Test Pressure (pneumatic)	As per manufacturer standard
Control Panel	
Type	Microprocessor panel in IP55 panel, Programmable, BMS interfaced (MODBUS)
Chilled water temp ^{0}C	Entering And Leaving Temperature Status
Ambient Temp	Ambient Air Temperature Status
Oil Pressure	Measuring Device To be provided
Compressor	No. of Running Compressor
Starter Type	Soft starter
Panel	
Material	M.S Heavy Gauge / G.I.
Door	Control Interlock
Paint	Anti Corrosive – Powder Coating Duly Treated For Corrosion
IP Rating	IP55 (Rain tight)
System Protection	
Low Suction Pressure	System Shut Down
High Discharge Pressure	System Shut Down
Freeze Protection	System Shut Down
Motor Protector/Mechanical High	System Shut Down

Low Evaporator Temperature	System Shut Down
Low Ambient Temp	Chiller Shut Down
Low Leaving Chilled Liquid Temp	Chiller Shut Down
Under Voltage Safety	Unit Shut Down
Compressor Failure	Alarm And Tripping
Anti Recycle	Tripping
Winding Temp. Sensor	Tripping

Notes:

14. Chillers shall be as per DMRC specifications. Any deviations to the specifications should be pointed out at tendering stage.

15. Chiller Motor starter shall be Soft starter without transient type.

16. Above data is not by way of limitation. Whatever is required for making the unit complete to meet the intent of specifications shall be deemed to have been included in the scope of work.

17. Flexible Connections at chiller shall be provided.

18. Over current, phase reversal, single phasing protections and KW meter shall be provided.

19. Refrigerant sensor shall be installed.

20. Performance rating.

21. The unit shall be selected for the lowest operating power consumption and noise level. Computer selected capacity rating and power consumption with operating points clearly indicated, shall be submitted with the tender as per technical data specified in the tender on full and partial load and shall be verified at the time of testing and commissioning of the installation. The gear losses should be included in the IKW/TR figures indicated by the bidders.

22. Capacity and power consumption shall be computed from the measurements of incoming voltage, input current, temperature (inlet & outlet) and water flow rate. Necessary provision shall be kept for providing flow meter and transducers required for computing capacity.

23. The supplier has to confirm that the IKW/TR data for the chilling unit submitted by him has been selected at the specified operating parameters and at constant condenser entering water temperature.

24. Also the machine shall be rated for actual capacity at specified conditions.

Only AHRI / Eurovent certified chilling machine shall be acceptable and the computer performance sheet. duly certified as per AHRI / Eurovent shall be submitted along with the technical submittal.

Section A05: Water Circulating Pumps

TABLE OF CONTENT

A05.1. General

A05.1.1. This section specifies the requirements for furnishing, installing and testing the water circulating pump sets complete with all accessories specified herein.

A05.1.2. The pump sets shall be the product of one single Manufacturer whose name shall appear on all submittals.

A05.2. Quality control

A05.2.1. The following codes, regulations, references, standards and specifications apply to the work of this section.

A05.2.1.1. American Society of Mechanical Engineers (ASME) or Equivalent IS

ASME PTC 8.2 – 1990	Centrifugal pumps

A05.2.1.2. Hydraulic Institute (HI)

ANSI/HI 1.1 – 1.5 (1994)	Centrifugal pumps or equivalent IS
ANSI/HI 1.3.4 (1997)	Centrifugal pumps – Horizontal base plate design or Equivalent IS
ANSI/HI 9.1.9.1 (1994)	General guidelines or Equivalent IS
ANSI/HI 9.6.3 (1994)	Allowable operating regime/Equivalent IS

A05.2.1.3. IS 6595:2002 or latest — Horizontal centrifugal pumps

A05.2.2. Submittals

A05.2.2.1. Before providing the pump Manufacturer with Notice to Proceed, the Contractor shall submit to the Employer for his review and consent the following data (not limited to):

(1) Theoretical pump performance curves for equipment proposed to be furnished under the contract.

- The pump performance curves form shut off to free delivery shall have the following data plotted as ordinate versus flow in cubic meters per hour as abscissa:
  - Head in m
  - Efficiency
  - Kilowatt input to the pump
  - NPSH required in m
- The curve shall be for the recommended operating speed of the pump

(2) A motor data sheet for each pump giving the following information at the operating point of the pump.

- Current in ampere
- Speed in revolutions per minute
- Efficiency in percent
- Power factor in percent
- Torque in Nm

(3) Manufacturer's Quality Assurance Program

(4) Total head to be overcome by the pump listed in a tabular form including but not limited to the following:

- Pressure loss in the connected equipment at the operating/duty conditions
- Pressure loss in the piping with piping length measured from working drawing to be performed during final design stage
- Pressure loss in all pipe fittings like elbows, reducers and tees
- Pressure loss in piping accessories like regulating and controlling valves, flexible connections, sensor wells and probes
- Head due to change in elevation

A05.3. Technical and installation requirements

A05.3.1. The pump sets shall be split case type with flanged connections directly mounted on TEFC squirrel cage induction motor and suitable starter as specified. The pumps should have anti corrosion coating, Efficiency enchancing coating/ investment casting on the inside of the casing and exterior (colour) finish should be same as that of the chillers.

A05.3.2. The impeller shall single entry shrouded design. The pump efficiency shall be 80% minimum for Primary secondary and condenser water pumps. For monoblock the pump efficiency shall be minimum 65%.

A05.3.3. Water seal shall be of mechanical type to minimise water leakage and should be easily serviceable in the field.

A05.3.4. Motor and starter shall conform to relevant specifications and of ratings given in "Bill of Quantities".

A05.3.5. The pump set shall be with horizontal/vertical split case type as per the data sheet/Bill of Quantities.

A05.3.6. The pump casing shall be high density cast iron or cast steel volute design machined to a close tolerance.

A05.3.7. The shaft shall be of high tensile Stainless steel mounted in generously sized bearings.

A05.3.8. The impeller shall be of Bronze and should be properly balanced.

A05.3.9. The shafts seal shall be of mechanical type to withstand leakage at high working pressure .suitable to operating pressure.

A05.3.10. A suitable flexible coupling shall be provided to connect the pump and the motor

A05.3.11. The base plate shall be suitable for mounting the motors and the pumps.

A05.4. VARIABLE SPEED SECONDARY CHILLED WATER PUMPING SYSTEM

A05.4.1 **General**

The scope of this section comprise the supply, erection, testing and commissioning of variable speed secondary chilled water pumping system conforming to these specifications as per Equipment Schedule.

System shall consist of the following:

1 Secondary pumps of type and capacity as specified in Equipment Schedule.

2 Programmable logic pump controller.

3 Adjustable frequency drives with manual by pass.

4 Remote sensor / transmitter.

5 Other items as required to properly execute the sequence of operation.

A05.4.**2** SECONDARY PUMPS

A05.4.2.1 The capacity of secondary chilled water pumps shall be in accordance with Equipment Schedule and Schedule of Quantities.

A05.4.2.2 The pumps shall be of split casing/Inline type. Pump casing shall be close-grained cast iron of heavy section, horizontal/vertical split, making possible complete servicing of rotating parts without breaking piping or motor connections. Motor to pump connection shall be of the smooth entry to impeller and increased efficiency. Impeller shall be bronze or gun metal, double suction, enclose type, hydraulically balanced and passages smooth-finished for minimum friction and maximum efficiency. Shaft shall be stainless steel, protected by gunmetal sleeves extending through stuffing boxes. Stuffing boxes shall be supported in ball/journal bearings, grease lubricated, contained in easily removable housing. Pumps shall be fitted with an air valve, two grease lubricators, drain plug and water seal connections. Mechanical seals shall be provided with all pumps.

A05.4.2.3 Pump motor shall be energy efficient having the efficiency class of IE-2, totally enclosed, fan-cooled, class-F insulation and suitable for operation on AFD. Motor shall be specially designed for quiet operation and its speed shall not exceed 1495 rpm. The motor rating shall be such as to ensure non overloading of the motor throughout its capacity range. Motor shall be suitable for 3-phase 415 + 10% volts, variable frequency power supply.

A05.4.2.4 Pump base shall be of 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.

A05.4.2.5 The pump shall be installed on a concrete inertia base as per section A14.

A05.4.2.6 Each pump shall be provided with certified performance curves showing power absorbed and corresponding flow rates by varying the speed. The tests shall be done at factory and may be witnessed by Consultant/Owner.

A05.4.2.7 Split casing pumps, prior to testing shall be aligned with a dial indicator within 0.05mm.

A05.4.2.8 Pump performance curves and power consumption with operating points clearly indicated shall be submitted and verified at the time of testing and commissioning of the installation.

A05.4.2.9 Pump performance shall be computed from the pump curves provided by manufacturer. All pumps shall be tested at factory as per relevant codes.

A05.4.3 **PUMP LOGIC CONTROLLER**

A05.4.3.1 The pump logic controller assembly shall be listed by and bear the label of Underwriter's Laboratory INC. (UL). The controller shall meet Part 15 of FCC regulations pertaining to class A computing devices. The controller shall specifically designed for variable speed pumping application. Pump logic controller shall be suitably interfaced with Adjustable Frequency Drive.

A05.4.3.2 The controller shall function to a proven program that safeguards against hydraulic conditions including:

a) Pump flow surges

b) Hunting

c) End of curve

d) System over pressure

A05.4.3.3 The pump logic controller shall be capable of receiving up to 3 dicrete analoge variable signal inputs from sensors/transmitters. It shall 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 stabilisation 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 four pumps in parallel.

A05.4.3.4 The pump logic controller shall have an additional analogue input for a flow sensor. This input shall serve as the criteria for the end of curve protection algorithm.

A05.4.3.5 The hydraulic stabilisation program shall utilize a proportional-integral-derivative control function. The proportional, integral and derivative values shall be user adjustable over an infinite range.

A05.4.3.6 The pump logic controller shall be self-prompting. All messages shall be displayed in plain English. The operator interface shall have the following features:

a) Multi-fault memory and recall last 10 faults and related operational data.

b) On-screen help function.

c) LED pilot lights and switches.

d) Soft-touch membrane keypad switches.

A05.4.3.7

A05.4.3.8 The following communication features shall be provided to the BAS:

a) Remote system start/stop non-powered digital input.

b) Failure of any system component. Output closes to indicate alarm condition.

c) One 4-20 mA output with selectable output of:

1. Frequency
2. Process Variable
3. Output Current

4. Output Power

A05.4.3.9 The following communication features shall be provided to Building automation System via an RS-485 port utilizing MODBUS protocol or any latest as per BMS requirements:

a) Individual Analog Input.

b) Individual Zone Set Points.

c) Individual Pump/AFD on/off status.

d) System percent speed.

e) System operation mode.

f) Individual KW signals.

g) System flow, when optional flow sensor is provided.

A05.4.4 ADJUSTABLE FREQUENCY DRIVE

A05.4.4.1 The adjustable frequency drive(s) shall be pulse width modulation (PWM) type, microprocessor controlled design.

A05.4.4.2 The AFD, including all factory installed options, be tested to UL Standard 508. The AFD shall also meet C-UL and be CE marked and built to ISO 9001 standards.

A05.4.4.3 The VFD shall be housed in a IP 20/ NEMA 1 enclosure. AFD's with plastic enclosures shall not be acceptable.

A05.4.4.4 The VFD shall employ an advanced sine wave approximation and voltage vector control to allow operation at rated motor shaft output speed with no derating. This voltage vector control shall minimize harmonics to the motor to increase motor efficiency and life. Power factor shall be near unity regardless of speed or load.

A05.4.4.5 The VFD shall have balanced DC link reactors to minimize power line harmonics. VFD's without a DC link reactor shall provide a 3% impedance line reactor.

A05.4.4.6 Automatic motor adaptation (AMA) algorithm shall be utilized. This feature shall allow for automatically optimized drive performance and efficiency leading to additional energy savings.

A05.4.4.7 Input and output power circuit switching can be done without interlocks or damage to the VFD.

A05.4.4.8 The following customer modifiable adjustments shall be provided:

a. Accel .time

b. Decel .time

c. Minimum frequency

d. Maximum frequency

A05.4.4.9 The VFD shall be compatible to interface with RS 485 utilizing MODBUS Protocol or latest.

A05.4.4.10 An automatic energy optimization selection feature shall be provided. This feature shall reduce voltages when lightly loaded and provide a 3% to 10% additional energy savings.

A05.4.4.11 The AFD shall be suitable for elevations as per requirement above sea level without derating. Maximum operating ambient temperature shall not be less than 104 degrees F. AFD shall be suitable for operation in environments up to 95% non-condensing humidity.

A05.4.4.12 The AFD shall be capable of displaying the following information in plain English via a 40 character alphanumeric display:

a. Frequency
b. Voltage
c. Current
d. Kilowatts per hour
e. Fault identification
f. Percent torque
g. Percent power
h. RPM

A05.4.4.13 All AFD's shall be warranted for a period of 18 months after shipment. This warranty shall cover parts and labour.

A05.4.5 SENSOR / TRANSMITTERS

Provide field mounted differential pressure sensor transmitter(s) as indicated on 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 stainless steel wetted parts with two 0.25" male NPT process connections. It shall be protected against radio frequency interference and shall have a watertight, NEMA 4 or IP 65 electrical enclosure capable of withstanding 10 bar static pressure with a 0.5" NPT conduit connection. Accuracy shall be within ±0.25%.

A05.4.6 **SEQUENCE OF OPERATION**

A05.4.6.1 The system shall consist of a pump logic controller, multiple pump/AFD sets, with manual and automatic alternation and pump staging [wherever applicable].

A05.4.6.2 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.

A05.4.6.3 When the pump logic controller selector switch is in the LOCAL position, and start command is given via operator interface, the pumping system shall operate automatically.

A05.4.6.4 Sensor / transmitters shall be provided as indicated on the plans.

A05.4.6.5 Each sensor/transmitter shall send a 4-20mA signal to the pump logic controller, indicative of process variable condition.

A05.4.6.6 The pump logic controller shall compare each signal to the independent, engineer/user determined set points.

A05.4.6.7 When all set points are satisfied by the process variable, the pump speed shall remain constant at the optimum energy consumption level.

A05.4.6.8 The pump logic controller shall continuously scan and compare each process variable to its individual set point and control to the least satisfied zone.

A05.4.6.9 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 [wherever applicable].

A05.4.6.10 The lag pump shall accelerate resulting in the lead pump(s) decelerating until they equalize in speed [wherever applicable].

A05.4.6.11 Further change in process variable shall cause the pumps to change speed together [wherever applicable].

A05.4.6.12 When the set point criteria can be safely satisfied with fewer pumps, the Technologic pump logic controller shall initiate a timed destage sequence and continue variable speed operation [wherever applicable].

A05.4.6.13 As the worst case zone deviates from set point, the pump logic controller shall send the appropriate analog signal to the AFD to speed up or slow down the pump/motor.

A05.4.6.14 In the event of a AFD fault, the pump logic controller automatically initiates a times sequence of events to start the redundant pump/AFD set in the variable speed mode. The redundant variable speed system shall be started through the pump logic controller.

A05.4.6.15 Upon AFD fault(s), the pump controller shall display an alarm condition through a plain English message.

A05.4.6.16 AFD fault indication shall be continuously displayed on the operator interface of the pump until the fault has been corrected and the controller has been corrected and the controller has been manually reset.

A05.4.6.17 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.

A05.4.6.18 Upon sensor failure a plain English warning message shall be displayed on the operator interface of the pump logic controller.

A05.4.6.19 In the event of failure to receive all zone process variable signals, a user selectable number of AFDs shall maintain a user adjustable speed, reset shall be automatic upon correction of the zone failure.

A05.4.7 QUALITY ASSURANCE

A05.4.7.1 The pumping package shall be assembled by the pump manufacturer. An assembler of pumping systems not actively engaged in the design and construction of centrifugal pumps shall not be considered a pump manufacturer. The manufacturer shall assume “Unit responsibility” for the complete pumping package. Unit responsibility for interface and successful operation of all system components supplied by the pumping system manufacturer.

A05.4.7.2 The manufacturer shall have a minimum of 5 years experience in the design and construction of variable speed pumping systems.

A05.4.7.3 All functions of the variable speed pump control system shall be tested at the factory prior to shipment. This test shall be conducted with motors connected to AFD output and it shall test all inputs and program execution specific to this application.

A05.4.7.4 The manufacturer shall be fully certified by the International Standards Organisation per ISO 9001. Proof of this certification shall be furnished at time of submittal.

A05.4.7.5 Manufacturer shall be listed by Underwriter's Laboratories as manufacturer of packaged pumping systems.

A05.4.7.6 Tenderer shall comply with all sections of this specification relating to variable speed pumping systems. Any deviations from this specifications shall be clearly defined in writing at time of bid. If no exceptions are taken at time of bid, the supplied shall be bound by these specifications.

A05.4.8 PAINTING

All variable pumping system, pumps, motors and bases shall be supplied with approved finish. Shop coat 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 adjoining areas.

DATA SHEET FOR CHILLED WATER PUMP (Primary)	
Type	End Suction Chilled water primary pumps
Reference Code / Standards	ISO : 9906 / IS 9079
Tag No	Tag No To Be Marked On Pump With Black Letter. SS Tag To Be Firmly Attached
Total Number	As per BOQ
Service	Continuous Duty
Capacity LPS	As per BOQ
Operating Head KPa	As per BOQ
Operating Pressure	As per system requirements
Noise Criteria	
Number Of Stages	Single Stage
Impeller	
Material	Bronze
Casing Material	Cast Iron ASTM AI59 43000
Balancing	Statically and Dynamically Balanced
Lock Nut	Bronze or ASTM A276 type 304
Pump Speed (nominal)	1495 RPM (Maximum)
Shaft	
Seal	Mechanical Type
Bearing Drive End	Roller Bearing / Ball Bearing
Bearing Non – Drive End	Ball Bearing
Material	High Tensile SS

Sleeve	Renewable Sleeve
Mounting	Shaft Key And Positive Locking Device
Packing	Graphited Cotton
Stuffing Box	Cast Iron / Mild Steel
Connection	
Suction	Flange Type Horizontal
Discharge	Flange Type Vertical
Flange	Drilled to as per BS Standard, Suitable for ANSI 125
Flexible	Yes – On Both Suction And Discharge
Drive Arrangement	Direct – With Flexible Coupling And Coupling Guard
Direction Of Rotation	Anti Clock Wise / Clock Wise From Driving End
Motor	
Type	TEFC Induction Motor (IP – 55), IE2
Design	As Per IEC 34 – 1, IEC 72 – 1
RPM	1495(Max)
Power Supply	Three Phase, 415 V, 50 Hz, AC Power Supply
Vibration Isolation	Inertia Base, Spring Isolation
Mounting Arrangement	Suitable Base Frame For Floor Mounting
Lifting Arrangement	Lifting Eye At Suitable Location And Number
Paint	Epoxy Paint, After Surface Treatment For Corrosion

Notes
1. Pumps shall be provided with common base frame, inertia base, spring vibration isolation pads, suction& discharge pressure gauges with isolation valves, test and / or air vent cocks, gland drain & other accessories as required.
2. Pumps starters shall be star delta air break type
3. Pump head given is approximate and vendor shall do their own calculations and offer the pumps accordingly.
4. Pump motor shall be IE2, non-overloading up to out off conditions riding over complete curve.

DATA SHEET FOR SECONDARY CHILLED WATER PUMP	
Type	Horizontal/Vertical Split Casing Chilled water secondary pumps
Reference Code / Standards	ISO : 9906 / IS 9079
Tag No	Tag No To Be Marked On Pump With Black Letter. SS Tag To Be Firmly Attached
Total Number	As per BOQ
Service	Continuous Duty
Capacity LPS	As per BOQ
Operating Head KPa	As per BOQ
Operating Pressure	12.30 Kg / cm^2

Noise Criteria	85 dbA at 1.5 meter.
Number Of Stages	Single Stage
Impeller	
Material	Bronze
Casing Material	Cast Iron ASTM AI59 43000/Cast Iron Gr.200
Balancing	Statically and Dynamically Balanced
Lock Nut	Bronze /(ASTM A276 Type)
Pump Speed (nominal)	1495 RPM (Maximum)
Shaft	
Seal	Mechanical Type
Bearing Drive End	Roller Bearing / Ball Bearing
Bearing Non – Drive End	Ball Bearing
Material	EN-8 / High Tensile SS
Sleeve	Renewable Sleeve
Mounting	Shaft Key And Positive Locking Device
Packing	Graphited Cotton
Stuffing Box	Cast Iron / Mild Steel
Connection	
Suction	Flange Type Horizontal / Vertical
Discharge	Flange Type Vertical / Horizontal
Flange	Drilled to as per BS Standard, Suitable for ANSI 125
Flexible	Yes – On Both Suction And Discharge
Drive Arrangement	Direct – With Flexible Coupling And Coupling Guard
Direction Of Rotation	Anti Clock Wise / Clock Wise From Driving End
Motor	
Type	TEFC Induction Motor (IP – 55), IE2
Design	As Per IEC 34 – 1, IEC 72 – 1
RPM	1495 (Max)
Power Supply	Three Phase, 415 V, 50 Hz, AC Power Supply
Vibration Isolation	Inertia Base, Spring Isolation
Mounting Arrangement	Suitable Base Frame For Floor Mounting
Lifting Arrangement	Lifting Eye At Suitable Location And Number
Paint	Epoxy Paint, After Surface Treatment For Corrosion

Notes

1. Pumps shall be provided with common base frame, inertia base, spring vibration isolation pads, suction& discharge pressure gauges with isolation valves, test and / or air vent cocks, gland drain & other accessories as required.
2. Pumps starters shall be star delta air break type
3. Pump head given is approximate and vendor shall do their own calculations and offer the pumps accordingly.
4. Pump motor shall be IE2, non-overloading over the entire operating range.
5. The pumps shall be provided with suitable coupler sleeves. The coupling shall be shielded by a dual rated complaint coupling guard and contain viewing windows for inspection of the coupling.
6. Each pump shall be factory hydrostatically tested per hydraulic institute standards.
7. The pumps shall be manufactured, assembled and tested in an ISO 9001 approved facility.
8. Each pump set shall be provided with variable frequency drive suitably interfaced with other system components for manual/auto operation.
9. The pump logic controller suitable for controlling three pumps in parallel shall be provided.
10. Pump Motor shall be non overloading over the entire operating Range.

DATA SHEET FOR CONDENSER WATER PUMP	
Type	Horizontal Split Casing Condenser water pump
Reference Code / Standards	ISO : 9906 IS :1520 IS : 9137 & 10596
Tag No	Tag No To Be Marked On Pump With Black Letter. SS Tag To Be Firmly Attached
Total Number	As per BOQ
Service	Continuous Duty
Capacity LPS	As per BOQ
Operating Head KPa	As per BOQ
Noise Criteria	85 dbA at 1.5 meter. Distance
Acoustic Treatment	As required to achieve the above
Number Of Stages	Single Stage
Impeller	
Material	Bronze
Casing Material	Cast Iron ASTM AI59 43000
Balancing	Statically & Dynamically Balanced
Lock Nut	Bronze(ASTM A276 Type)
Pump Speed (nominal)	1495 RPM (Maximum)

Shaft	
Seal	Mechanical Type,
Bearing Drive End	Roller Bearing/Ball Bearing
Bearing Non – Drive End	Ball Bearing
Material	EN-8 / High Tensile SS
Sleeve	Renewable Sleeve
Mounting	Shaft Key And Positive Locking Device
Packing	Graphited Cotton
Stuffing Box	Cast Iron / Mild Steel
Connection	
Suction	Flange Type Horizontal
Discharge	Flange Type Vertical
Flange	Drilled To BS Standard, Suitable for ANSI 125
Flexible	Yes – On Both Suction And Discharge Ends
Drive Arrangement	Direct – With Flexible Coupling And Coupling Guard
Direction Of Rotation	Anti Clock Wise / Clock Wise From Driving End
Motor	
Type	TEFC Induction Motor (IP – 55), IE2
Design	As Per IEC 34 – 1, IEC 72 – 1,
RPM	1495 (Max)
Power Supply	Three Phase, 415 V, 50 Hz, AC Power Supply
Vibration Isolation	Inertia Base, Spring Isolation
Mounting Arrangement	Suitable Base Frame For Floor Mounting
Lifting Arrangement	Lifting Eye At Suitable Location And Number
Paint	Epoxy Paint, After Surface Treatment For Corrosion

Notes

1. Pumps shall be provided with common base frame, vibration isolation pads, suction& discharge pressure gauges with isolation valves, test and / or air vent cocks, gland drain & other accessories as required.
2. Pumps starters shall be star delta air break type
3. Pump head given is approximate and vendor shall do their own calculations and offer the pumps accordingly.
4. Pump motor shall be IE2, non-overloaded up to the run out conditions riding over complete curve.

DATA SHEET FOR CHILLED WATER PUMP (Primary) FOR AIR COOLED CHILLER	
Type	End Suction / Monoblock Chilled water primary pumps
Reference Code / Standards	ISO : 9906 / IS 9079
Tag No	Tag No To Be Marked On Pump With Black Letter. SS Tag To Be Firmly Attached

Total Number	As per BOQ
Service	Continuous Duty
Capacity LPS	As per BOQ
Operating Head KPa	As per BOQ
Operating Pressure	6 Kg / cm^2
Noise Criteria	85 dbA at 1.5 meter.
Number Of Stages	Single Stage
Impeller	
Material	Bronze
Casing Material	Cast Iron ASTM AI59 43000
Balancing	Statically and Dynamically Balanced
Lock Nut	Bronze
Pump Speed (nominal)	1495 RPM (Maximum) for 4 Pole 2995 RPM (Maximum) for 2 Pole
Shaft	
Seal	Mechanical Type
Bearing Drive End	Roller Bearing / Ball Bearing
Bearing Non – Drive End	Ball Bearing
Material	EN-8 / High tensile stainless steel strength
Sleeve	Renewable Sleeve
Mounting	Shaft Key And Positive Locking Device
Packing	Graphited Cotton
Stuffing Box	Cast Iron / Mild Steel
Connection	
Suction	Flange Type Horizontal
Discharge	Flange Type Vertical
Flange	Drilled to as per BS Standard, Suitable for ANSI 125
Flexible	Yes – On Both Suction And Discharge
Drive Arrangement	Direct – With Flexible Coupling And Coupling Guard
Direction Of Rotation	Anti Clock Wise / Clock Wise From Driving End
Motor	
Type	TEFC Induction Motor (IP – 55), IE2
Design	As Per IEC 34 – 1, IEC 72 – 1
RPM	1495 (Max) for 4 Pole 2995 (Max) for 2 Pole
Power Supply	Three Phase, 415 V, 50 Hz, AC Power Supply
Vibration Isolation	Inertia Base, Spring Isolation
Mounting Arrangement	Suitable Base Frame For Floor Mounting
Lifting Arrangement	Lifting Eye At Suitable Location And Number
Paint	Epoxy Paint, After Surface Treatment For Corrosion

<table>
<tr><td></td><td></td></tr>
<tr><td colspan="2">Notes
1. Pumps shall be provided with common base frame, inertia base, spring vibration isolation pads, suction& discharge pressure gauges with isolation valves, test and / or air vent cocks, gland drain & other accessories as required.
2. Pumps starters shall be star delta air break type
3. Pump head given is approximate and vendor shall do their own calculations and offer the pumps accordingly.
4. Pump motor shall be IE2, non-overloading up to out off conditions riding over complete curve.</td></tr>
</table>

Section A06: Ductworks, dampers, diffusers and accessories

TABLE OF CONTENT

A06.1. General

A06.1.1. Description

A06.1.1.1. This Section specifies the manufacture and installation of ductwork, diffusers, registers, grilles, dampers, guide vanes, cleaning of air system, access panels and accessories.

A06.1.1.2. All ductwork and distribution accessories delivered to Site shall be new and indelibly stamped to identify different grades, materials and manufacturers.

A06.1.1.3. Provide all ductwork, diffusers, registers, dampers and grilles generally in accordance with the Drawings to be performed during final design stage.

A06.1.1.4. Diffusers, registers and grilles shall be selected to meet the requirements of noise control as described elsewhere in this Specification.

A06.2. Quality control

A06.2.1 Relevant Codes and Standards

- HVCA, DW/144: Specification for Sheet Metal Ductwork, Low, Medium and High Pressure/Velocity Air Systems
- BS 476: Fire Tests on Building Materials and Structures
- BS 729: Hot Dip Galvanised Coatings on Iron and Steel Articles
- UL 555: Fire Dampers
- UL 555S: Leakage Rated Dampers for Use in Smoke Control Systems

A06.2.2 SMACNA: HVAC Duct Construction Standards, metal and Flexible and Rectangular Industrial Dust Construction Standards (Note: SMACNA standards shall be applied only if any part of the duct installation standards are not covered by DW/144).

A06.3. Technical and installation requirements

A06.3.1. Sheet Metal Ductwork

A06.3.1.1. All sheet metal and stainless steel ducting shall be constructed to the recommendations of DW/144. The pressure class rating shall also be in accordance with DW/144.

Ductwork shall be constructed of galvanised steel sheets complying to DW144 for sheet thickness. The galvinization on ductwork shall be 275 GSM.

A06.3.1.2. Provide volume control dampers, complete with adjusting handle or similar device to all branches of the supply air ducts to regulate air flows along the main duct and the branch ducts. Provide opposed blade type volume control dampers to all branch.

A06.3.1.3. Provide flexible connectors of not less than 100 mm long between primary air handling units/air handling units/fans and related ductwork to prevent transmission of vibration to adjacent elements. Flexible connectors shall also be provided at building/station expansion and movement joints.

A06.3.1.4. The material used for the flexible connections shall withstand the specified conditions of temperature and air pressure, and shall comply with the standards of air-tightness. The material shall be fire resistant.

A06.3.1.5. Provide access doors in ducts where required to gain access to fans, silencers, dampers, filters or controls for cleaning and future maintenance.

A06.3.1.6. Access doors and panels in ductwork shall be quick release type with handles. Multiple screw fixings will not be accepted. The doors shall be of air-tight construction with gasket mounted on the periphery of door frame.

A06.3.1.7. Provide flanged joints to plant and elsewhere as necessary to facilitate maintenance.

A06.3.1.8. All flanged joints in ductworks shall be made up with rubber gaskets or suitable mastic material. These joints should also be connected with suitable material for earthing. Proper sized electrical continuity jumpers (min. 2 per joint) is required to be provided for making the duct work continuous. The gaskets provided should be fire retardent and should not emit toxic gases in case of fire.

A06.3.1.9. Apply sealant, adhesives, tapes to joints for sealing. All such material shall comply with the requirements of DW/144.

A06.3.1.10. Balancing dampers of appropriate types shall be provided for air balancing.

A06.3.1.11. Short radius rectangular and square elbows in air ducts shall be equipped with double thickness turning vanes. Long radius elbows shall be used wherever possible.

A06.3.1.12. The transition ductwork between silencers and fans shall be constructed of not less than 1.2mm thick galvanised steel sheet. The transition shall be aligned with the fans and shall be connected with angle flanges.

A06.3.1.13. The ducts and supports in the stations must be adequate for minimum 100mm wg static pressure or the system pressure whichever is higher.

DATA SHEET FOR NON FIRE RATED DUCT MATERIAL AND DUCT WORK	
Duct Material	Galvanized Sheet Steel Of Lock Forming Quality
Zinc Coating	275GSM
Reference codes / Standards	Duct Construction DW 144 / SMACNA(only for parts not covered in DW144)
Duct	All Duct Sections Will Be Cross Broken
Guide Vanes	At All the Bends To Be Made From The Same Material As The Duct
Thickness Of Sheet And Type Of Joint for Rectangular Duct	As per DW144
Traverse Joint	
Large side upto 1000mm	TDF type Flange
Large side 1000mm and above	Slip On Flange
Bracing/Support	Indicative support arrangement is given in tender drawing, final drawing shall be approved by engineer in charge
Duct Accessories	
For Joints	Hexagonal Nuts – Bolts / Washers Zinc Coated
Rivets	Galvanized Iron / Magnesium Aluminum Alloy

Gaskets	Fire retardant– size as per flange requirement
Screws	Self Tapping Screws Will Not Be Used
Support Arrangement	As Per SMACNA/DW144
Support From Wall / Ceiling	Anchor Fastener Of Required Rating Not Less Than 2.5 Times the Load of the Duct
Paint	Flanges And Supports Treated For Corrosion And Painted With Zinc Rich Paint Of Approved Quality
Flexible Connection circular Spigots	Fire Proof Material To Be Screwed Or Clip Band With Adjustable Screw Or Toggle Fitting
Flexible Connection Rectangular Ducts	Fire Proof Material To Be Flanged And Bolted With Backing Flat Or Bolted To Mating Flange With Backing Flat
Flexible Connection	150 mm Length Between Two Faces (Minimum)

A06.3.2. Flexible Ducts

A06.3.2.1. Flexible ducts shall be neatly fixed and adequately supported.

A06.3.2.2. Flexible ducting used to connect the air distribution accessories and main ductworks shall comply with Part 7 of DW/144.

A06.3.2.3. Flexible duct length shall not exceed 3.7m in length. Sheet metal duct branch off shall be provided in case the maximum length of flexible duct permitted is not long enough to reach the air terminal.

A06.3.2.4. Bending radius shall be sufficient to prevent undue tensioning of the outside of the bend and restriction of the throat likely to cause deformation and/or leakage. The ratio between the bending radius and the duct diameter shall be less than 2. In no case shall flexible ductwork be used to connect misaligned ducts.

A06.3.2.5. Flexible duct shall consist of flexible corrugated metal tubing of stainless steel, aluminium, tin plated or aluminium coated steel and suitable for an operating temperature range of –5 to 9°C.

A06.3.2.6. The frictional resistance to air flow per unit length of flexible duct shall not exceed 150% of the frictional resistance per unit length of galvanised steel duct of similar diameter.

A06.3.2.7. Flexible duct shall be insulated and wrapped with a minimum 25mm thick 24kg/m^3 density fibre glass blanket.

A06.3.2.8. Flexible duct shall not be used for any system which is designed for handling smoke or being part of a smoke control system.

A06.3.3. Fusible Link Fire Dampers (FLFD)

A06.3.3.1. Provide fire dampers in air ducts where ducts penetrate fire compartments.

A06.3.3.2. Fire dampers shall fully comply with the requirements of DW/144.

A06.3.3.3. Fire dampers shall be constructed to the same standards of air tightness as the rest of the system.

A06.3.3.4. Fire damper casings and blades shall be constructed of galvanised sheet (275 GSM) and provided with a galvanised steel angle frame to each side of wall or floor.

A06.3.3.5. Fire damper casings shall be flanged to suit the ductwork which they are fitted and the cross-sectional area shall not be less than that of the ductwork.

A06.3.3.6. Blade and fusible link shall be accessible for servicing through air-tight inspection doors placed upstream or downstream of the air path whichever provides the better access.

A06.3.3.7. Provide UL Listed fusible link set at 68°C / 74°C or else as approved to all fire dampers unless otherwise specified. Fusible link shall be arranged in an exposed position and at upstream of the damper.

A06.3.3.8. Details and position of all fire damper and associated access doors shall be submitted for Approval prior to installation on Site.

A06.3.3.9. Provide all necessary fixing framework for the installation of fire dampers.

A06.3.3.10. Provide fire rated material to seal off the clearance between the fire dampers and wall.

<u>DATA SHEET FOR FIRE DAMPER</u>		
Type		Fusible Link Snap Acting (FLFD)
Reference Code / Standard		UL 555 BS 476 Part 20.,UL Classified
Fire Rating		Two Hour @ 250^0 C
Fusible Link		Rated @ 68^0 C /74^0 C
Service		Continuous Duty
Mounting		Horizontal Or Vertical
Construction		In Single / Two Module
Differential Pressure		1000 Pascal
Damper Free Area		75 % Of Damper Face Area
Damper Operating Mounting Bracket		As per manufacturer standard complying UL555
Open / close Indication		Limit Switch With Each Module
Leakage		Max 5% Of The Rated Air Flow Across Damper In Open Position
Frame Construction		As per manufacturer standard complying UL-555
Blade		
	Pressure Drop	38 Pascal @ 10 Mtr. / sec. Air Velocity
	Construction	Material As per manufacturer standard complying UL-555 Design – Aerofoil Design OR 3V-Type Design
	Type	Opposed/parallel Blade as per requirements
	Blade Thickness	For Aerofoil Design – Min 1.6mm For 3V-Type Design – Min 1.5mm Both complying UL-555
	Linkages	As per manufacturer standard complying UL-555
	Shaft	As per manufacturer standard complying UL-555
	Bearing	As per manufacturer standard complying UL-555

A06.3.4. Paint/Covering and Fire Rated Ductwork

A06.3.4.1. Where shown on the Drawings, fire rated ductwork or equipment enclosure shall be fabricated from fire rated material to the requirements of BS 476 Part 24 or ISO 6944.

A06.3.4.2. Not used

A06.3.4.3. The construction of the ductwork or enclosure shall take into account the structural strength, noise isolation as required and the requirements of **Class C** duct in accordance with DW/144. The galvinization on ductwork shall be 275 GSM.

A06.3.4.4. All necessary supports, and other accessories required for the complete installation of fire rated ductwork, Sealent, Gasket, including additional material for fire stopping at wall/ceiling penetration, shall be supplied by the same manufacturer as the fire rated duct material and shall be assembled in accordance with all the manufacturer's recommendation regarding all aspects of construction and installation shall be certified by the manufacturer.

A06.3.4.5. The applicable smoke temperature shall be 250 deg C. The ductwork system shall be fire-rated for two hours and shall maintain mechanical stability, fire resistant integrity, and thermal insulation criteria to BS 476: Part 24 as per the ISO Cellulosic Fire Curve at temperature of 1029 °C, for both vertical and horizontal duct arrangements, for both inside and outside fire exposures. Restriction of the duct due to twisting or buckling after the fire test shall not cause 25 % or more reduction in cross-sectional duct area.

A06.3.4.6. The performance shall not be affected by moisture absorption. Mechanical strength shall be maintained and the fire resistance material shall not de-laminate or the fire resisting properties shall not deteriorate even under water saturation. The material shall also be "Class-One" surface spread of flame as defined in BS 476: Part 7. Additional insulation, if required, shall be used as per the manufacturer's recommendation.

A06.3.4.7. Whether BS 476 thermal insulation criterion is applicable or not, fire rated air-conditioning supply, return, and exhaust ductwork shall be complete with thermal insulation and vapour barrier.

A06.3.4.8. The fire resistant material shall not attract pests and shall not rot or support the growth of mould.

A06.3.4.9. All fire resistant ductwork or enclosure, apart from its fire resisting quality, shall be capable of resisting accidental damage and shall require to pass the hard body impact test section of BS 5669: Part 1 / BS EN 1128 with the weight being dropped through not less than 1m.

A06.3.4.10. Smoke extraction system ductwork shall be made from suitable material with adequate thickness. Rivets or self sealing screws used shall not be of aluminium. Where ductwork (including sealant, flexible connection, gasket and accessories) for smoke extraction / purge systems penetrate the fire compartment walls or floors of the room which they serve, the portion of the ductwork that traverses outside of the compartment wall or floor shall have a fire rating equal to the fire rating of the compartment wall or floor which it traverses through or of not less than two hours whichever is the higher.

A06.3.4.11. Fire resistant and acoustically sealed access panels shall be provided in the above-mentioned enclosures for the access and maintenance of equipment and fire dampers.

<table>
<tr><td colspan="4">DATA SHEET FOR FIRE RATED DUCT MATERIAL AND DUCT WORK</td></tr>
<tr><td colspan="3">Duct Material</td><td>Galvanized Sheet Steel Of Lock Forming Quality</td></tr>
<tr><td colspan="3">Fire Rating</td><td>Two Hour @ 250^0 C</td></tr>
<tr><td colspan="3">Zinc Coating</td><td>275 GSM</td></tr>
<tr><td colspan="3">Reference codes / Standards</td><td>Duct Construction BS 476 PART 24, ISO 6944.</td></tr>
<tr><td colspan="3">Duct</td><td>All Duct Sections Will Be Cross Broken</td></tr>
<tr><td colspan="3">Guide Vanes</td><td>At All the Bends To Be Made From The Same Material As The Duct</td></tr>
<tr><td colspan="3">Thickness Of Sheet And Type Of Joint for Rectangular Duct</td><td>As per DW144</td></tr>
<tr><td></td><td colspan="2">Traverse Joint</td><td></td></tr>
<tr><td rowspan="3"></td><td colspan="2"></td><td></td></tr>
<tr><td colspan="2">Large Side upto 1000 mm</td><td>TDF Type</td></tr>
<tr><td colspan="2">Large Side 1001 – 2250 mm</td><td>Slip on flange</td></tr>
<tr><td></td><td colspan="2">Bracing</td><td>Indicative support arrangement is given in tender drawing, final drawing shall be approved by engineer in charge</td></tr>
<tr><td rowspan="3"></td><td colspan="2"></td><td></td></tr>
<tr><td colspan="2"></td><td></td></tr>
<tr><td colspan="2"></td><td></td></tr>
<tr><td></td><td colspan="2">Duct Accessories</td><td></td></tr>
<tr><td rowspan="5"></td><td colspan="2">For Joints</td><td>Hexagonal Nuts – Bolts / Washers Zinc Coated</td></tr>
<tr><td colspan="2">Rivets</td><td>Galvanized Iron / Magnesium Aluminum Alloy</td></tr>
<tr><td rowspan="2">Gaskets</td><td>Material</td><td>Fire Rated For 250^0 C 2 hours</td></tr>
<tr><td>Thickness</td><td>As per flange requirements</td></tr>
<tr><td colspan="2">Screws</td><td>Self Tapping Screws Will Not Be Used</td></tr>
<tr><td colspan="3">Joint Strength</td><td>Should With Stand 1.5 Times the Operating Pressure With Out Deformation Or Failure</td></tr>
<tr><td colspan="3">Support Arrangement</td><td>As Per SMACNA/DW144</td></tr>
<tr><td colspan="3">Support From Wall / Ceiling</td><td>Anchor Fastener Of Required Rating Not Less Than 2.5 Times the Load of the Duct</td></tr>
<tr><td colspan="3">Paint</td><td>Flanges And Supports Treated For Corrosion And Painted With Zinc Rich Paint Of Approved Quality</td></tr>
<tr><td colspan="3">Flexible Connection circular Spigots</td><td>Fire Proof Material To Be Screwed Or Clip Band With Adjustable Screw Or Toggle Fitting</td></tr>
</table>

Flexible Connection Rectangular Ducts	Fire Proof Material To Be Flanged And Bolted With Backing Flat Or Bolted To Mating Flange With Backing Flat
Flexible Connection	150 mm Length Between Two Faces (Minimum)
Duct Material	Fire Rated To Comply With BS – 476 Part 24 And ISO – 6944
Reference Standard	BS 476 Part 24, ISO – 6944
Flame And Fire Spread	Class O (BS 476 Part 6 & 7)
Fire Duct Work	Manufactured to HVCA Standard DW-144
Function	Smoke Extraction
Duct Material	Resistant to Water Impingement From Any Sprinkler System
Impact Resistance	BS EN 1128
Stability And Integrity	Must Retain at least 75% of its overall Cross Sectional Area (BS – 476 Part 24 (1987)
Leak Test	HVCA Specification DW – 143
Sealant	Flame Retardant
Duct Accessories	
Supports And Angle	Should Have 800^0 C Melting Point And Tensile Stress is 15 N / mm2 For min 2Hour
Hangers And Stiffeners	
Flanges	
Gasket And Nut / Bolts	
Duct Work Seals	As Per BS – 476 Part 24, ISO – 6944

A06.3.5. Motor Operated Dampers (MOD)

A06.3.5.1. All motor operated dampers shall be suitable for installation in either a vertical plane or a horizontal plane.

A06.3.5.2. The dampers shall be operated by electric actuators and shall be readily assembled on Site from modular panels. Each motor operated damper panel shall be of the multiple-parallel-blade type, with an independent channel frame; and shall be factory-assembled complete with frames, blades, shafts, bearings, seals, linkage, and all accessories required to erect the panels into composite dampers. Motor operated dampers shall be provided with all structural support members and hardware required for installation with additional framing or trims as required to complete the installation.

A06.3.5.3. Motor operated damper actuator shall be mounted outside of the damper frame.

A06.3.5.4. Spring-return type damper actuator shall be provided either to open or close damper as required in the event of power failure.

A06.3.5.5. All motor operated dampers shall be the product of a single manufacturer; and all like components shall be provided by a single supplier.

A06.3.5.6. Motor operated damper module assembly shall have a net free face area of not less than 75% measured to the inside of the frames.

A06.3.5.7. Dampers shall be based on standard air having a density of 1.20 kg/m^3. This shall apply to MOD and MSFD/MFD.

A06.3.5.8. The motor operated damper manufacturer shall carry out factory tests to verify that when the dampers are fully-closed and holding against a differential pressure of 1000 Pa, air leakage through the damper will not exceed 8 CFM per square feet of net damper face area.

A06.3.5.9. When the dampers are in the fully-open position and air is flowing across the damper at a uniform velocity of 10 m/s and the static-pressure drop across the damper shall not exceed 38 Pa.

A06.3.5.10. The motor operated dampers and their associated structural-supporting systems shall, when the dampers are in the fully - closed position, be capable of withstanding a differential pressure across the dampers of not less than 1.5 kPa.

A06.3.5.11. The motor operated damper blade and shaft assemblies shall be supported at each end by means of heavy duty, permanent self-lubricating bronze or stainless steel bearings.

A06.3.5.12. All motor operated damper-blade seals and damper-frame seals shall be fabricated of a flexible material suitable for the specified operating conditions as Approved. The seals shall be factory-installed in dovetail grooves incorporated for this purpose in the design of the blade and frames to facilitate a tight closure between the blades, and between the blades and frame. All seals shall sit securely in the closed damper position. Alternative design of the seals will be subject to the Approval of the Engineer. Noise due to resonance of spring-type seals or any other source shall be rejected.

A06.3.5.13. Each module of damper with only two operating positions should have one limit switch with two contacts to monitor its open/closed status. If any one module of the damper fails to operate, the damper shall be considered not functioning properly. For each module of damper with three operating positions, two or more limit switches shall be provided.

A06.3.5.14. Motor operated damper linkage shall consist of stainless steel (SS-316), extending through bearings inserted in brackets fabricated of stainless steel. The linkage bearings shall be fabricated from bronze or other material suitable for the specified operating conditions as Approved. The linkage brackets shall either be attached to the damper-blade shafts or be side-mounted and mechanically inter-connected with the shafts. Set screws shall not be used in the linkage assembly. The linkage for MFD shall be as per manufacturing standard complying UL555 and UL555S.

A06.3.5.15. Motor operated damper frames shall be a channel cross-section with not less than a 100 mm web and 40 mm flanges, and shall be fabricated of hot-dipped galvanised steel plate (min. 275 GSM) to BS EN 10142. However, the web and frame for MFD shall be as per manufacturing standard complying UL555 and UL555S. Reinforcing bosses and dove-tail grooves for mounting frame seals shall be integral parts of the channel configuration. The corners of the frames shall be either welded or reinforced by means of riveted gusset plates.

A06.3.5.16. All screws, bolts, nuts, washers, expansion anchors, and/or other hardware required to complete the installation shall be fabricated from stainless steel grade 316, and all intermediate supports, framing members, and hardware required for assembly/installation of the damper shall be fabricated of hot-dipped galvanised steel to BS 729.

A06.3.5.17. The motor operated dampers shall be installed using fastening devices and structural support elements herein specified, and in accordance with the published instructions of the damper manufacturer.

A06.3.5.18. Motor operated damper blades shall have an aerofoil or 3V design with minimum thickness of 2mm, and shall be fabricated of hot-dipped galvanised steel plate (min. 275 GSM) to BS EN 10142 . The width of the blades, measured in the direction of airflow shall not be less than 100 mm and shall not be greater than 200 mm. For MFD, blades shall be aerofoil design (min 1.6mm) or 3V design (min 1.5mm).

A06.3.5.19. Motor operated damper-blade shafts shall be fabricated of stainless steel SS-316,. The design of the shafts shall incorporate the devices required for securely locking the blades onto the shafts. For MFD, shafts shall be as per manufacturing standard complying UL555 and UL555S requirements.

A06.3.5.20. All VCDs, and MDs shall also comply with above specifications to the extent applicable. VCDs shall have provision to set & lock the damper at any desired position, whereas, MDs shall have a two position set and lock facility only. These would be made of GSS (275 GSM) with 2 mm frame and blades.

A06.3.6. Motorised Smoke and Fire Dampers (MSFD/MFD)

A06.3.6.1. MSFD/MFD, FMDs shall comply with FSD requirements and as specified above for MOD, with the following additional requirements:

A06.3.6.2. MSFD/MFD frames and other components made of steel shall be hot-dipped galvanised and shall not be painted. Damper blades shall be fabricated of galvanised steel. All unprotected edges shall be touched up with an Approved paint-on type zinc-based protective coating.

A06.3.6.3. MSFD/MFD design and construction materials shall be submitted for Approval and shall conform to the high temperature ratings as specified on the Equipment Schedules and/or Drawings.

A06.3.6.4. MSFD/MFD shall comply with BS 476: Part 20 or UL 555 and Class I to UL 555S. MSFD/MFD shall be tested in accordance with the procedure specified in UL 555S with respect to the requirements of elevated temperature and air leakage of the MSFD/MFD.

A06.3.6.5. MSFD/MFD shall have a minimum fire rating to match with the FRP requirement of the structural elements where the MSFD/MFD is mounted.

A06.3.6.6. All materials used for the construction of the MSFD/MFD shall be so selected and all components and accessories of the dampers shall be so designed that the dampers will be fully operational in accordance with the performance requirements specified when fully exposed in an air stream temperature of 250°C for not less than two hour. Accessories shall include electric actuators, limit switches and any other damper status sensing devices.

A06.3.6.7. Actuator shall be of sufficient torque to ensure tight closure of the damper, and shall be capable of being detached with ease to allow manual operation of the damper. The actuator shall be provided with spring return to close or open as required by the design in case of power failure.

A06.3.6.8. All VCDs and MFDs shall also comply with the above specifications to the extent applicable. In addition, VCFs shall have provision to set and lock the damper in any position, whereas, FMDs shall have a two position set and lock facility only.

A06.3.6.9. MSFD/MFD shall be UL classified.

DATA SHEET FORMOTORISED SMOKE & FIRE DAMPERS FOR ECS	
Type	Motorized Damper For ECS
Reference Code / Standard	UL 555S, UL 555, BS 476 Part 20.
Fire Rating	Two Hour @ 250^{0} C

Service	Continuous Duty
Mounting	Horizontal Or Vertical
Construction	Each module With Dedicated Motor Actuator
Differential Pressure	1500 Pascal
Damper Free Area	75 % Of Damper Face Area
Damper Operating Mounting Bracket	As per Manufacturing standard complying UL555 & UL555S
Open / close Indication	Limit Switch With Each Module
Leakage	Leakage as per Class 1 of UL555S
Frame Construction	As per Manufacturing standard complying UL555 & UL555S
Blade	
Pressure Drop	38 Pascal @ 10 Mtr. / sec. Air Velocity (As per size)
Construction	Material - As per Manufacturing standard complying UL555 & UL555S Design – Aerofoil Design OR 3V Design
Type	Parallel/ Opposed Blades
Blade Thickness	For Aerofoil Design – Min 1.6mm For 3V-Type Design – Min 1.5mm Both complying UL555 & UL555S
Linkages	As per Manufacturing standard complying UL555 & UL555S
Shaft	As per Manufacturing standard complying UL555 & UL555S
Bearing	Self Lubricated Sleeve Bearing
Bearing Rating	OneHour @ 250^0 C
Crank Arms	As per Manufacturing standard complying UL555 &UL555S
Actuator Assembly	
Capacity	50% In Excess Of The Rated Capacity
Differential Pressure	1500 Pascal
Temperature Rating of actuator assembly	Two Hour @ 250^0 C
Motor Type	Single Phase, 220 V, 50 Hz, AC Supply
Accessories	Space Heater
Indication	Power On – Off
1. Sleeve thickness of dampers shall be same as the frame thickness	

A06.3.7. Guide Vanes

A06.3.7.1. Guide vanes shall be provided as required to maintain an acceptable system pressure loss.

A06.3.7.2. All blanking plates and sealing plates shall be provided for a complete installation.

A06.3.7.3. Vanes, supports, stiffeners, flanges, washers, bolts and welding filler shall be of galvanised steel (275 GSM) and constructed to the recommendations of DW/144.

A06.3.7.4. Vanes shall be of continuous seam welded construction, except for stiffening ribs, which may be stitch welded. Welding shall be in accordance with relevant British Standards.

A06.3.7.5. Curved sections shall be rolled or alternatively formed by a series of creases in a break press as long as the creases are closely spaced, not obstructive and form a smooth profile of air flow. If a break press is to be used, a sample of a section of vane shall be submitted for Approval.

A06.3.8. Ductwork Installation

A06.3.8.1. Provide complete ductwork systems and ensure that the installation can be adjusted to the designed flow rates to the satisfaction of the Engineer.

A06.3.8.2. Check all the Drawings provided in regard to structural requirements and other finishes before detailing the ducting system. Allowance shall be made for the detailed development and on Site co-ordination.

A06.3.8.3. Submit all drawings to indicate the fabrication and installation of ductwork for Approval before fabrication commences.

A06.3.8.4. Replace damaged ductwork and other appurtenances at no additional cost to the Employer.

A06.3.8.5. Provide hangers and supports (Slotted rail), fabricated of hot-dipped galvanised steel, for the proper installation of ducts in accordance with DW144/SMACNA and approved standard drawing. Hanger rods shall be minimum 10 mm in diameter, depending on size of duct. All such hangers shall be provided with screwed lengths on lower end for adjustment of ducting runs to level. All nuts shall be provided with washers and with lock-nuts, and projecting ends of bolts shall be cut off.

A06.3.8.6. Supports shall not be riveted or bolted to the air ducts.

A06.3.8.7. Install dampers and splitters in a manner so that they can be adjusted at any time after completion of the work.

A06.3.8.8. Install dampers without strain or distortion of any part of the dampers.

A06.3.8.9. Adjust moving parts to move freely without binding.

A06.3.8.10. Caulk dampers airtight around frames.

A06.3.8.11. Adjust dampers and splitter adjusting rods to operate freely, between the open and closed position.

A06.3.8.12. Install flexible connections in accordance with Part 7 of DW/144.

A06.3.8.13. All ductwork shall be manufactured according to the dimensions taken on Site. Provision shall be allowed to accommodate any discrepancies between the Drawings and the Site dimensions.

A06.3.8.14. All branches and openings in ducts shall be purpose made prior to erection of the ductwork.

A06.3.8.15. Cross-breaking will be permitted on low velocity ductwork only and in no case where rigid external insulation shall be applied.

A06.3.8.16. Internal roughness, sharp edges or obstructions to air flow shall not be allowed.

A06.3.8.17. External edges and corners formed from cleated joints shall be neatly dressed down with air tight joints.

A06.3.8.18. Provide at least 75 mm clearance from ductwork to walls, ceiling and obstructions where a high standard of cleanliness shall be maintained.

A06.3.9. Diffusers, Registers and Grilles Installation

A06.3.9.1. Install diffusers, registers and grilles so that they can be key adjusted from the face directly without special tools.

A06.3.9.2. Unless otherwise specified, install vanes, volume control dampers and multiple-blade extractors so that they can be removed through the diffusers and registers for access to the duct.

A06.3.9.3. Install diffusers, grilles, registers and louvres with frame connected to the ductwork and provide soft gaskets inserted under the frame or otherwise so arranged so as to avoid air leakage around the diffusers and grilles.

A06.3.10. MOD and MSFD/MFD Installation

A06.3.10.1. Each damper shall be installed so as to provide smooth operation, opening and closing without shock in accordance with the manufacturer's recommendations.

A06.3.10.2. Undue flexing or bending of connecting rods and linkage will not be acceptable. Such connecting rod or linkage shall be replaced with either a corrected design, higher strength material or increased size of such a component at no extra cost to the Employer.

A06.3.10.3. Dampers shall be supported independently of the ductwork.

A06.3.10.4. Wall and floor mounted dampers: All slight, unavoidable spaces and purpose-provided spaces between the damper frames and the structure shall be sealed as required or as Approved. Blanking-off plates for such purpose shall be considered as part of the damper assembly and shall be provided at no additional cost to the Employer.

A06.3.10.5. Damper module installations shall be fully sealed by gaskets between the module frame and the mounting frame. The gasket material for MSFD/MFD shall meet the continuous operation in an air stream temperature of 250°C for not less than two hour criteria. Identification of damper position is required on easy visible and accessible position, and the damper setting position after balancing shall be marked in a permanent manner.

A06.3.11 **Air Duct Cleaning points**

A06.3.11.1 The Contractor shall supply and install air duct cleaning points access doors at suitable locations to the duct work system. The cleaning points shall be installed at fully accessiable locations. The contractor shall also supply proprietary type compressed air lance, disinfection application lance and ambling probe which shall be suitable for use with the cleaning points. All joints must be air/water tight to prevent leakage.

A06.3.12 **Grills and Diffusers**

A06.3.12.1. All grills and diffusers shall be designed and rated in accordance with ASHRAE 32-7/ASHRAE 70.

A06.3.12.2. All grills and diffusers shall be of pure polyester finish aluminium unless otherwise specified. Colour of grills and diffusers shall be selected by the Engineer. Samples of finishes shall be submitted for approval.

A06.3.12.3. All supply, return and exhaust diffusers shall be complete with opposed blade dampers, suitable for mounting with appropriate diffuser and shall be fitted with concealed adjustment devices. Straightner grids are required before diffusers except for the last diffuser on the route. Each supply air grille shall be complete with an opposed blade multi-leaf damper. One set of tool for every 10 grilles or diffuser shall be provide for volume adjustment.

A06.3.12.4. Grilles and diffusers shall be same paint finish from outside and inside as per approved shade. The drawings show provisional locations of diffusers and grilles but in each instance outlets shall be installed in accordance with the final detail drawings and reflected ceiling plans.

A06.3.12.5. Velocities, net airways and distribution patterns shall give satisfactory air distribution and temprature equalisation, be free of draughts stratification or noise nuisance. The contractor shall make final adjustments to air patterns when balancing.

A06.3.12.6. The sizes of the grilles (including linear grille) indicate on drawings imply the neck sizes of the fittings. Whereas the sizes of ceiling diffusers on drawings imply overall external dimensions.

A06.3.12.7. **Square ceiling Diffusers**

- Diffusers constructed of extruded aluminium shall be power coated polyester finish to a colour approved by the Engineer.
- Diffusers with removable cores shall have square necks or alternatively round necks. Diffuser sizes are shown on the drawings.
- Provide aluminium or steel opposed blades volume control dampers of black colour with concealed adjustment lever. In general, dampers will not be required for fan coil unit system having supply diffuser.
- Provide galvanised steel sheet painted black at the front view to seal off dummy parts of diffuser.
- Diffusers ring or frames shall be compatible with the ceiling construction in which they are installed. A transition piece shall be provided to connect the diffuser to the duct. All edges exposed to view shall be rolled or otherwise stiffened and rounded. Internal parts shall be removable to permit cleaning of the diffuser and provide access to the duct.
- Baffles, turning vanes or other devices shall be provided for the required air distribution pattern. Equalising grids shall be provided for ceiling diffusers.
- Volume control dampers shall be equipped and factory fabricated by the diffuser manufacturer . The adjustment position shall be easily accessed.
- Square and rectangular diffusers shall comply with the following performance requirements at design flow :
  - Maximum pressure drop : 30 Pa
  - Throw : 4m
  - Noise criteria : NC 30
  - Maximum air velocity at diffuser neck : 4 m/s
  - Maximum terminal velocity : 0.5 m/s

A06.3.12.8. **Supply and Transfer Air Grilles and Register for general use.**

- Double deflection supply air grilles/register shall be tapped from top or bottom of ducts with provision for tamper proof adjustment of air pattern spread along its width. Adjusting tool shell be provided by the manufacturer. Grilles/register shall have a minimum of 75% free area.

- Provide grilles/registers to meet the size and capacities as shown in the drawings required to connect ducts to grilles and registers.
- Grilles and register shall be factory assembled with opposed blade volume control dampers operable through the grilles face. The adjustment shall be by a key through the face of the register and the volume control damper shall be group operated or opposed blade type. The operating mechanism shall not project through any part at the register face.
- Diffusers constructed of the extruded aluminium shall be pure polyester finish o a colour approved by the Engineer.
- All grille cores shall be capable of being removed easily from the duct work of access to dampers.
- All edges exposed to view shall be rolled or otherwise stiffned and rounded. All edges shall be equipped with air tight, non-combisible neoprene or sealing stips to prevent leakage. The register ring of frames shall be compitable with ceiling construction in which they are installed.
-
- Supply air registers shall comply with the following performance requirements at design flow as :
    - Maximum presuure drop : 30 Pa
    - Throw : 4m
    - Noise criteria : NC 30

A06.3.12.9. **Return/Exhaust Grilles and Registers for General use**

Grilles shall have single set of fins which shall be vision proof to effectively mask the return opening. Grilles shall have 45^0 inclined fins spaced approximately 19 mm apart.

Free area of grille core shall be at least 75%.

Grilles and registers will be fixed type.

Return air diffusers shall match the supply diffusers in appearance and shall be constructed of the same material and identical in surface finish as approved by the Engineer.

Register rings or frames shall be compatible with the ceiling construction in which they are installed.

A06.3.12.10. **Linear Air Diffusers**

Each diffusers shall be of single/multi-slotted vertical/horizontal discharge, ceiling mounted type fitted into a field-insulated boot with spigot for receiving supply air duct as detailed on the drawings.

Diffusers of extruded aluminium shall be power coated polyester finish to a colour as approved by the Engineer.

Number of slots and lengths of diffusers and capacity shall be as indicated on the drawings.

Provide air boot to the diffusers as shown on the drawings. Air boot casing shall be constructed of 0.6 mm thick galvanised steel with interior surfaces insulted to prevent erosion. Insulation and air boot shall be extended to cover the collar of diffuser. Volume control dampers shall be provided in the air boot spigot.

Subject to the ceiling panel design, the flanges of the diffusers shall be designed to support “drop in “ceiling pane.

Provide suitable support points independent of suspended ceiling for the air boots and the associated diffusers.

Air boot spigot location and dimensions shall generally be as indicated on the drawings.

Provide galvanised steel sheet painted black at the front view to seal off the dummy part of the diffusers.

Linear air diffuser shall comply with the following performance requirements at design flow as :

- Maximum presuure drop : 30 Pa
- Throw : 6m
- Noise criteria : NC 35
- Minimum terminal velocity : 0.5 m/s

A06.3.12.11. **Nozzle/Jet Diffusers**

Nozzle/Jet diffuser assembly shall consist of round diffuser element which shall be fitted to square or rectangular back plate, opposed blade volume damper and duct collar.

Each nozzle/Jet diffuser assembly shall consist of the diffuser element and shall be compitable with the architectural design in which they are installed.

Individual diffuser element shall be capable of adjusting the air deflection upto 30^0 from any plane perpendicular to the face. Adjustment shall be accomplished from front or back of the diffuser without tools.

Volume control dampers shall be provided for the diffusers.

The Nozzle/Jet diffuser shall comply with the following performance requirements as design flow:

- Maximum presuure drop : 60 Pa
- Throw : 15m
- Noise criteria : NC 35

DATA SHEET FOR GRILLS AND DIFFUSER FOR ECS	
Function	Air Distribution
Standard	Air Diffusion Council
Requirement	For Supply Air, Return Air And Air Extraction
Grills	Linear Flow / Double Deflection Registers
Diffuser	Four Way Rectangular / Square / Round
Construction Material	Aluminium and thickness minimum 1.3 mm

Flange	As per manufacturer standard Suitable For Continuous Joint With Alignment Strips
Design	Extruded section
Blade / Louvers	Adjustable Front and Rear
Bars	
Front	Aluminium
Rear	Aluminium
Damper	
Type	Adjustable Lever Operated
Fire Rating	Non Fire Rated
Finish	Black Anodized
Paint	Material Duly Treated for corrosion And Anti Corrosive Paint
Noise Generation	Should Have Very Low Air Noise Generation

A06.3.13 Access Door

A06.3.13.1. Gasketed airtight access doors shall be provided at the duct for access, inspection and maintenance of fans, equipment, dampers, filters, smoke probes and controls.

A06.3.13.2. Doors shall be hinged type complete with minimal of two sash locks and shall be made of same metal thickness as ducts. Doors shall have suitable size to access.

A06.3.13.3. Access doors for insulated ductwork shall be of double skin construction with insulation in between. The insulation for the access doors shall be of the same type and thickness as the adjacent ductwork.

A06.3.13.4. The door panels shall be made of suitable material and they shall have not less than 12 mm wide neoprene rubber gasket around the entire perimeter to ensure air tightness. It shall have the same fire rating as the adjacent duct construction.

A06.3.13.5. The access doors shall be hung on approved heavy duty hinges and provided with suitable quantity with locks. The locks shall be able to operate both from inside and outside. Where it is impracticable to use hinge doors, the access doors may be fixed in position with wedge type locks on opposite sides with suitable quantity per door. The section of the duct where the access door is located shall be reinforced with suitable material.

A06.3.13.6. Where the duct is of smaller dimensions than the access door specified, the door shall be of the full width of the duct Sealant and gasket used shall be in accordance with the recommendations of HVCA, DW/144 Specification.

A06.3.14 Manual Damper & Volume Control Damper

DATASHEET FOR MANUAL DAMPER & VOLUME CONTROL DAMPER FOR ECS	
Type	Manual Damper
Operation	Lever Arrangement, For Adjustment And Locking At Any Position
Service	Continuous Duty
Mounting	Horizontal Or Vertical
Construction	Splitter, Butterfly Type
Damper Free Area	75 % Of Damper Face Area
Damper Operating Mounting Bracket	Galvanized Steel
Leakage	Less than 0.1m3/s/sqm of net damper face area
Frame Construction	Galvanized Steel
Blade	
Pressure Drop	38 Pascal @ 10 Mtr. / sec. Air Velocity or as per manufacturer standard
Construction	Aerofoil design/3V design, Galvanized Steel
Type	For Manual Damper - Parallel/OpposedBlade For VCD – Opposed Blade
Material	Galvanized Steel
Thickness	2.0 mm Thick
Linkages	Stainless Steel – 316
Shaft	Stainless Steel – 316,
Bearing	
Type	Bush Bearing
Material	Brass
Handle	Suitably Supported For Ease of Movement, sufficient strength and shall be made of similar material and shall be easy to operate.
1. Damper shall be factory tested for fully closed position and holding against a different pressure of 1000 Pa and air leakage through the damper shall not exceed 0.1m3/s/sqm of net damper face area as per specification.	

Section A07: **Insulation**

TABLE OF CONTENT

A07.1. General

A07.1.1. This Section specifies the manufacture and installation of thermal insulation for ECS plant and services.

A07.2. Quality control

A07.2.1. Relevant Codes and Standards
BS 476: Fire Tests on Building Materials and Structures

A07.2.2. Not used

A07.2.3. Material used for fire rated insulation shall comply with BS476-Part 4 and qualify as non-combustible material. Material used for non-fire rated insulation, if not complying with BS476-Part-4, shall qualify as class 'O' material according to BS476: Part-6 and Part-7.

A07.2.4. Not used

A07.3. Technical and installation requirements

A07.3.1. The materials, thickness and finishes for insulation applied for various services are specified as:
Semi-rigid fibre glasswool or rockwool applicable on duct and pipe wrapped with a factory applied vapour barrier jacketing secured in position with adhesive and fixing pin/retaining washers. Vapour barrier shall be aluminium foil kraft paper, fire resistant adhesive and reinforced with fibre glass yarn. The kraft paper shall be permanently treated to assure permanent fire and smoke safety, and to prevent corrosion of the foil.

A07.3.1.1. Areas of flat insulation with any dimension greater than 1200mm shall have galvanised fixings equal to the thickness of the insulation secured to the surface with self-sealing aluminium 'pop' rivets to provide firm fixing for finishes. The insulation of non fire rated ductwork shall have:

- Minimum density: 32kg/m3 for glass wool and 64 kg/m3 for Rockwool (Density as per BOQ)
- Maximum K-factor: 0.035W/mK at 25°C mean temperature
- Temperature range: 0 to 120°C
- Thermal Resistance or R-value shall be as per ECBC code

A07.3.1.2. Insulation of fire rated duct work shall have

- Minimum density : 120 kg/m3
- Maximum K-factor : 0.052W/mK at 100°C mean temperature as per ASTM C335/ASTM C518/IS 8183/IS 3346
- Temperature range: 0 to 800°C

A07.3.1.3. No asbestos based insulation material shall be used.

A07.3.1.4. Not used

A07.3.1.5. Flexible elastomeric pipe insulation shall be of fire-retardant, flexible, close-cell, CFC free, in continuous lengths, with factory applied talc coating on inner surface. Flexible elastomeric insulation shall have a flame spread rating of 25 or less and a smoke developed rating of not over 150 for 12mm thickness, in accordance with ASTM E84 test method.

- Maximum K-factor : 0.04W/mK at 20oC mean temperature
- Density: 64kg/m3 for pipes, 80kg/m3 at supports
- Closed cell content: at least 90%
- Water vapour permeance: not exceeding 0.28 mgm/Nh
- Resistance to heat: at least 80^0 C.

A07.3.2. Finishes for Insulation

A07.3.2.1. Insulation inside false ceiling and service ducts shall not require any finish.

A07.3.2.2. 0.8mm thick aluminium hammerclad cladding firmly secured with 'pop' rivets evenly spaced at 100mm centres shall be applied to indoor insulation which is visually exposed to view inside station areas and within plant rooms. Cladding shall be provided with means of removal for repair and maintenance. The same cladding is to be provided on the chilled water pipes.

A07.3.2.3. 15mm cement plaster finish on chicken-wire mesh with additional finish of 0.8mm polyisobutylene sheeting with solvent weld joints shall be applied to outdoor type insulation which is exposed to ambient. The whole shall be then provided with a completely weatherproof external enclosure to the insulation. Corrosion proof bands and clips shall hold the sheeting tight against the insulation such that ballooning will not occur.

A07.3.3. Execution

A07.3.3.1. Insulation shall not be applied before the relevant plant or service has been satisfactorily inspected and tested.

A07.3.3.2. All insulation shall be applied by skilled workmen.

A07.3.3.3. Apply insulation on clean and dry surface with no foreign materials, such as oil, grease, rust, scale or any other dirt.

A07.3.3.4. Apply clean and dry insulation only.

A07.3.3.5. Install insulation in accordance with the manufacturer's recommendation as a minimum requirement.

A07.3.3.6. Provide a complete moisture and vapour seal wherever insulation terminates against metal hangers, anchors, or other projections through insulation on cold surfaces.

A07.3.3.7. Stagger all joints with respect to the adjacent butt joint. Seal with 50mm wide aluminium foil type for fibre glass insulation.

A07.3.3.8. Apply insulation in a manner to give an acceptable look, smooth and lineable surface of uniform thickness. Steps and undulations in the surfaces will be rejected by the Engineer.

A07.3.4. Insulation on Sheet Metal Ducts

A07.3.4.1. Cut insulation slightly longer than perimeter of duct to insure full thickness at corners.

A07.3.4.2. All insulation shall be applied with edges tightly banded.

A07.3.4.3. Adhesive shall be applied so that insulation conforms to duct surfaces uniformly and firmly.

A07.3.4.4. Provide metal fixing pins and retaining clips in addition to adhesive for securing of insulation.

A07.3.4.5. The protruding ends of the pins shall be cut off flush and the vapour barrier facing shall be thoroughly sealed with a vapour barrier mastic or tape where the pins have pierced through. Pin spacing shall not exceed 300mm on centres.

A07.3.5. Insulation of Pumps

A07.3.5.1. Fit insulation snugly against equipment without voids.

A07.3.5.2. Bevel curved surface edges to provide a tight joint.

A07.3.5.3. Provide metal insulated cover with metal fasteners, supports, frames and membranes.

A07.3.6. Piping

A07.3.6.1. Install same thickness insulation as the adjoining pipe insulation on flanges, valves and other fittings to obtain the maximum strength and security. Seal joints, protruding metal parts and valve stems thoroughly.

A07.3.6.2. All valves, traps, flanges and strainers shall be insulated in conformity with the pipework in which they are incorporated except that 1.2mm thick galvanised steel or aluminium split boxes shall be provided to ensure easy removal of insulation.

A07.3.6.3. Insulate strainers in such a manner to permit removal of gasket without disturbing the insulation of the strainer body. Insulate valves up to and including bonnets.

A07.3.7. Insulation and Protection at Pipe and Duct Supports

A07.3.7.1. Insulated pipes shall be provided with high-density rockwool insulation of minimum 160kg/m3 density.

A07.3.7.2. The collar shall not be less than 75mm width for pipe sizes up to 80mm diameter, 150mm width for pipe sizes up to 200mm diameter and 200mm for pipe sizes above 200mm diameter.

A07.3.7.3. Brackets shall be of same width as the collar.

A07.3.7.4. Insulation at pipe support shall be protected by galvanised sheet steel sleeve of 1.2mm in thickness and not less than 250 mm in length.

A07.3.7.5. For insulated pipes above 300mm diameter, steel bridging pieces will be allowed to penetrate the insulation to support the pipe. All annular space between support saddle and pipe shall be filled with insulation and the supports shall be adequately insulated to prevent condensation (for chilled water pipes).

A07.3.7.6. High density PUF supports shall be added between pipes and hangers.

A07.3.7.7. Vapour barrier shall be aluminiumfoil kraft paper, fire resistant adhesive and reinforced with fibre glass yarn.

DATA SHEET FOR INSULATION MATERIAL	
Function	Thermal Insulation (Roll / Slab And Pipe Sections)
Reference Code / Standard	BS – 476 ASTME – 136, ISO – 1182, IS – 11239, BS – 4735, BS – 5422
Material Density	32 Kg/m^3 for glass wool and 64 Kg/m^3 , 120 Kg/m^3 , 160 Kg/m^3 for rock woolMinimum)
Fire Rating	Two Hour @ 250^0 C for fire rated insulation
Thermal Conductivity	0.020 – 0.038 Kcal / Hr M ^{0}C, BS – 4370 Part 2, DIN – 52613
Water Transmission	2 % By Volume As Per ASTM C 1104 / 1104 M / IS3144
Mechanical Properties	Mechanical Strength As Per IS8183, IS3144
Combustion	Non-combustible as per BS476 for fire rated insulation Non-combustible or Limited combustible as per BS476 for non-fire rated insulation
Toxic / Smoke Density	Non toxic and non smoke producing as per code DIN – 4102, ISO – 5924 / ASTM D-5116
Smoke Density	ASTM E84 / ISO5924
Biological Properties	No Sustenance To Growth Of Fungi, Bacteria Or Vermin BS 3958 / ASTM C1338 / IS3144
Acoustics	Should Have Good Sound Absorption Efficiency
Cladding	0.8 mm Aluminum As Per ASHRAE Standard for ducts in ECS plant rooms and for pipes at all locations
Insulation Thick	
Supply Air duct	25 mm for Air- Conditioned areas and 50 mm inside plant rooms

Return Air duct	25 mm for Air- Conditioned areas and 50 mm inside plant rooms
Pipe	75 or 50 mm depending on the pipe dia as in specs.(160 kg/m^3 Rockwool)
Fire rated duct	100 mm with minimum density of 120 Kg/m^3

Section A08: Cooling towers

TABLE OF CONTENT

A08.1. General

A08.1.1. This section specifies the requirements for furnishing, installing, testing and commissioning cooling towers complete with all accessories as specified herein.

A08.1.2. The cooling towers shall be the product of a single Manufacturer whose name shall appear on all submittals.

A08.2. Quality control

A08.2.1. Thefollowing codes, regulations, reference standards and specifications apply to the work of this section.

ISO 9001:2008

Cooling Technology Institute (CTI)

Cooling Towers should be CTI certified as per latest CTI STD 201 Certification standard for cooling towers and shall demonstrate the performance test on selected sample in factory.

A08.2.2. **Submittals**

A08.2.2.1. Submit certificate of compliance that the design and fabrication of various components of the cooling towers meet the requirement of the Contract.

A08.2.2.2. Include data substantiating that materials comply with the requirements of the various standards as specified.

A08.2.2.3. Submit complete selection sheet, sound datasheet, performance curve, detailed unit drawing, load point analysis as supporting documents tocomply on various standards.

A08.3. Technical and installation requirements

A08.3.1. General

A08.3.1.1. The cooling towers shall be induced draft, Counter Flow/Cross flow type with vertical discharge complete with FRP basin, FRP body, fan and motor assembly, fill media, distribution pipes, etc.

A08.3.1.2. The Cooling tower shall be constructed with a sturdy structural Hot dipped Galvanized/ FRP frame designed to transmit all wind, seismic and mechanical Load to the equipment anchorage. The body shall be made of FRP sections of equal segments, all bolted together. The surface on both inside and outside shall be smooth, for minimum air resistance. The fan deck shall form an integral part of the body. The Casing panels shall be constructed of corrosion resistant and UV resistant fibre glass reinforced Plastic (FRP) with smooth finish to minimize air resistance and ensure prolong equipment life as per CTI Standard.

A08.3.1.3. The water basin shall be constructed of mimimum 4 mm thick Fibre glass reinforced plastic (FRP), having an auxiliary cylindrical suction tank, wherever required. The basin shall be completed with connections for drain, overflow, make up-water, quickfill and float valve, plus hot dipped galvanised suction strainer.

A08.3.1.4. The support structure for the tower shall be of mild steel duly sturdy structural hot dipped galvanised frame (750GSM) or FRP.

A08.3.1.5. The water diffusion deck shall be of rigid PVC fill as per manufacturer's standard, arranged in a suitable pattern for ease of replacement. The fill shall be rated and certified by the cooling tower manufacturer.

A08.3.2. Water distribution system

A08.3.2.1. The hot water distribution basin shall be open gravity type for easy cleaning and constructed with FRP and shall be distributed through a sprinkler system consisting of PVC sprinkler pipes, which shall be mounted on top of the main supply stand pipe. Alternately, the water distribution could be with a water diffusion deck.

A08.3.3. Fan assembly

A08.3.3.1. The Fans shall be heavy duty, axial flow with aluminium alloy blades selected to provide optimum cooling tower thermal performance with minimum sound levels.The fan blades shall be of aerofoil design and adjustable pitch. The fan assembly shall be statically and Dy namicallybalanced.

A08.3.3.2. The cooling tower shall be such that the exit air does not re-enter the cooling tower therby reducing the capacity of the tower.

A08.3.3.3. The Fans shall be driven by either by speed reduction gears or multigrooved V type belts with taper lock sheaves or direct driven type designed for 150 % of the motor nameplate horsepower. In case of Belt driven assembly, Belt shall be of proven design(already in service for moore than 5 years) and be specifically designed for cooling tower application. Fans and shafts shall be supported by heavy duty, self aligned, lubrication type or totally seal type bearings.One set of additional V belt set for one cooling tower shall be supplied with each cooling Tower.

A08.3.3.4. The fan motor shall be shall be of high efficiency class IE-2, totally enclosed fan cooled for gear and belt driven or TEAO in case of direct driven squirrel cage type conforming to I.P. 55 protection for outdoor operation designed specifically for cooling tower services. The motor shall be furnished with moisture protection on the windings, shafts and bearings and have watertight terminal box.

A08.3.3.5. The fan guard shall be hot dipped galvanised (min 750 GSM) with wire mesh screen to prevent bird nesting during idling period.

A08.3.3.6. All fasteners shall be of Stainless steel (SS-316).

A08.3.3.7. The air inlet area is to be provided with Stainless steel (SS-304) wire mesh and SS-304 louvers.

A08.3.4. Ladder

A08.3.4.1. All towers shall be provided with a ladder, made out of hot dipped galvanised M.S. (min. 750 GSM) to access the fan Deck. Handrails shall be provided along the ladder. Handrails shall also be provided on the top of cooling tower along the perimeter of the cooling tower cells. The ladder design shall be submitted for approval by Employer's representative.

A08.3.5. Noise level

A08.3.5.1. The noise emanating from the cooling towers, shall not exceed 85 dBA from the distance of 1 meter. Sound data sheet showing complete octave band should be submitted by the manufacturer.

A08.3.6. Installation

A08.3.6.1. Installation shall be carried out in a manner which shall fully comply with the Manufacturer's recommendations.

A08.3.7. Field tests

A08.3.7.1. General requirements are the following:

- Perform all tests in the presence of the Engineer
- Furnish all field test instruments. The Contractor may remove test instruments only after testing is completed.
- Provide labour, materials and appurtenances required to complete the specified field tests.
- Submit all testing standards and procedures for approval prior to proceeding with any of the tests.

A08.3.7.2. Not used

A08.3.7.3. Not used

A08.3.8 **Access Door**

A08.3.8.1 Suitable arrangement shal be provided for easy access into the plenum section for maintenance purpose.

DATASHEET FOR COOLING TOWER	
Type	Induced Draft,Cross Flow Type with Vertical Discharge, CTI CERTIFIED
Reference Code / Standard	CTI – STD 201-1991
Tag No	Tag No To Be Marked On Cooling tower With Black Letter. SS Tag To Be Firmly Attached
Total Number	As per BOQ
Heat Rejection Capacity	As per BOQ
Fluid	Water
Condenser Inlet Temp.	34.4 °C
Condenser Outlet Temp.	30.0 °C
Designed WBT	27.4 °C
Noise Criteria	85 dBA at 1 m
Water Flow Rate	as per BOQ of condenser water pump
Construction Material	Fiber Reinforced Plastic orsturdy Structural Hot Dipped

	Galvanized
Total Water Loss	1 % Max (combined drift and evaporative losses).
Water Basin – Material	Fiber Reinforced Plastic
Connections	
Size	As per manufactures standard
Inlet And Outlet	As per manufactures standard (Flanged)
Make Up	Regular Arrangement Suitable For Level Switch Controller And Ball Valve With Quick Fill Arrangement
Drain And Overflow	With Valve Arrangement In Drain
Fan	
Type	Aerofoil Design, Statically and Dynamically Balanced
Static	As per manufactures standard
Number of fans	Minimum Two Numbers
Blade / Hub	Cast Aluminum Alloy, EN-8
Bearing	Heavy Duty ,Self Aligned Grease Packed Bearing with moisture proof seals and integral slinger collars.
Guard	16 SWG Wire Mesh With Frame
Drive Arrangement	Direct driven or Speed reduction gears or V Type Belts
Motor	
Type	TEAO/TEFC – Induction Motor (IP– 55), With Weather Protection, IE-2 Class with service factor of 1.15
Design	IS 60034
Power Connection	Three Phase, 415 V, 50 Hz, AC Supply
RPM	1400 (Max)
Nozzles Design	As per mfg. Design
Nozzles Material	Poly Propylene / HDPE
Cells	As per manufacturers Standard
Number Of Cells	Two Cell
Accessories	Mounting Legs And Ladder With Hand Rails Minimum 300 mm Wide, Duly Treated For Corrosion, Inspection window
Header / Fittings	Galvanized Steel / PVC / HDPE
Base Frame and ladder	GSS/MS Hot Dipped Galvanized

Paint on base frame and ladder	Hot dipped Galvanized(minimum 750 GSM)
Thickness	Casing as per CTI standard and Basin-4mm (Minimum)
Height of cooling tower	As per manufactures standard

1. Cooling towers shall conform to specifications.
2. Local push buttons for C.T. motors shall be provided.
3. All hardware used for fixing of cooling tower shall be of SS 316
4. Level switch shall be provided for each cooling tower

Section A09: Pipe work

TABLE OF CONTENT

A09.1. General

A09.1.1. This section specifies the requirements for manufacturing, furnishing, installation and testing of pipe work related to ECS, complete with all required accessories.

A09.2. Quality control

A09.2.1. Material and workmanship shall be in accordance with the latest edition of the following standards and codes, and the materials shall be certified by the standard organisation.

IS 1239: Steel tubes, tubulars and other wrought steel fittings – specification Part 1 Steel Tubes

IS 1239: Steel tubes, tubulars and other steel fittings – specifications Part 2 Steel Pipe Fittings

IS 3589: Steel pipes for water and sewage (168.3 to 2540 mm outside diameter) - specification

A09.2.2. Submittals

A09.2.2.1. Certificate of the standards organisation testifying that the material furnished under this Contract comply with these standards.

A09.2.2.2. Details of all supports, hangers and accessories

A09.2.2.3. Manufacturer's quality assurance programme

A09.2.2.4. Test results: The Contractor shall submit certified test results conducted at the factory for the material being furnished by him which shall include but not limited to the following:

- Material test certificates giving the physical and chemical properties of the material used in the manufacture
- Hydraulic tests or alternatively by non destructive examination

A09.3. Technical and installation requirements

A09.3.1. Pipe material

A09.3.1.1. Chilled water system/Condenser water system:

- Nominal bore 50-150mm: black steel conforming to IS 1239 Part 1 heavy grade
- Outside diameter above 150mm upto 500mm: Black carbon steel manufactured by electric resistance welded using 410Mpa grade steel conforming to IS 3589
- Minimum wall thickness for pipes shall be:

Diameter (mm)	Wall thickness (mm)
200-300	6.3
350-400	8.0
450-600	9.5

700-800	12.5

A09.3.1.2. Condensate drain and vent piping system: Nominal bore 15-150: Galvanised steel to IS 1239 medium grade.

A09.3.1.3. Pipes shall bear the BIS standard mark indicating the relevant IS and manufacturer's name.

A09.3.2. Pipe fittings – Materials

A09.3.2.1. Chilled water system/Condenser water system: Galvanized steel fittings complying IS 1239 Part 2.

A09.3.2.2. Condensate drain and vent piping system: Galvanized steel fittings complying IS 1239 Part 2.

A09.3.3. Flanges

A09.3.3.1. Welded piping: Steel, welding neck pattern shall be used.

A09.3.3.2. Screwed piping: Galvanised steel screwed boss flanges or galvanised malleable cast iron screwed boss flanges.

A09.3.3.3. Copper tubing: Copper slip-on flanges for brazingshall be used. Galvanised iron bolts and nuts shall not be used for fixing copper flanges.

A09.3.4. Gaskets

A09.3.4.1. Gaskets shall be suitable for the temperature, service and pressure of the system and shall be installed in accordance with the Manufacturer's recommendations after obtaining approval for engineer in charge. Made-up flanged joints shall be fabricated from one-piece ring gaskets, 3mm thick, neoprene rubber.

A09.3.4.2. For flanged joints between dissimilar metals or insulating flange joints: insulating gaskets, sleeves and washers between flanges, bolts and nuts respectively shall be used. Insulating material shall be "Teflon" or approved equal.

A09.3.5. Jointing

A09.3.5.1. Chilled water/Condenser water systems: screwed sockets or welded joints for sizes up to 50mm; butt-welded joints for sizes 65 mm and above.

A09.3.5.2. Condensate drain and vent piping systems: screwed sockets joints for sizes up to 50mm; screwed flanges for pipe work 65mm and above.

A09.3.5.3. Chilled water/Condenser water systems: black malleable iron, bronze to iron spherical seat unions for pipework up to 50 mm diameter. Black mid steel welding flanges in accordance with the specified working pressure for pipework above 65mm diameter.

A09.3.5.4. For condensate drain and vent piping systems: Galvanised malleable iron, bronze to iron spherical seat unions for pipework up to 50 mm diameter. For pipes of 65 mm diameter and above, galvanised malleable iron, bronze to iron spherical seat unions or galvanised steel screwed boss flanges.

A09.3.5.5. For fan coil unit connections: Union or flange joints

A09.3.6. Supports and hangers

A09.3.6.1. A typical arrangement for pipework support is shown in figure. The supports shall be provided as per site requirements as approved by engineer in charge.

A09.3.6.2. Supports for insulated piping: segmented section of hardwood or high density phenolic/PUF insulation extending on either side of the support.

A09.3.6.3. Unless specified otherwise, hangers shall be of the following sizes:

Pipe diameter (mm)	Single rod diameter (mm)	Double rod diameter (mm)
15 to 50	10	10
65 and 80	13	10
100 and 125	15	13
150	20	15
200;250 and 300	22	20
Above 300	Hanger rod shall be designed with a safety factor of 5 ,based on the ultimate strength of the material used	

Protective coating

A09.3.7.1. Buried galvanised/steel pipes shall be protected from rusting with approved good quality bituminous paint and protective tapes.

A09.3.7. Installation

A09.3.8.1. A typical arrangement for pipework is shown in figure. The detaled installation arrangement shall be submitted for approval.

A09.3.8.2. The installation shall be neat and tidy, with accurate spacing between pipes, valves and joints, whether running in straight routes or turning through bends.

A09.3.8.3. Particular care shall be taken that all pipework is erected and secured truly parallel with the building structure, clear of obstructions, preserving headroom and keeping passageways clear and that all vertical drops are plumb.

A09.3.8.4. No bends or curves in any pipe shall be made so as to diminish the waterway or alter the internal diameter of the pipe.

A09.3.8.5. Wherever possible, horizontal pipes shall be fixed to ’fall’ to aid venting and draining down of the pipework. Eccentric reducing sockets shall be used on horizontal runs of pipe to prevent the formation of air pockets. On vertical pipes, concentric reducing sockets shall be used.

A09.3.8.6. Drain outlets shall be provided at all low points of the system to enable emptying and to facilitate maintenance of the pipework.

A09.3.8.7. Automatic or manual air vents shall be placed at each high point of each water line and discharge pipe shall be terminated at 50 mm above floor drain.

A09.3.8.8. Pipe runs, where exposed, shall be positioned at least 25 mm from the finished wall surfaces to enable subsequent cleaning and painting of all surfaces. Where pipe runs are installed at an angle, they shall be positioned 40 mm from the finished surfaces.

A09.3.8.9. All pipes shall be fitted clear of the floor to permit cleaning beneath the pipes. Where possible, a 125 mm clearance shall be provided between the underside of the pipe and the finished level of the floor and in no case shall the pipe be less than 100 mm clear of the floor.

A09.3.8.10. All pipe runs when not buried underground shall be concealed as far as possible by careful positioning or shall be chased into walls, or laid in screeds except inside plant rooms. All pipes which are to be concealed shall be tested and Approved before being covered.

A09.3.8.11. Where it is not possible to install the pipework with setting out dimensions as shown on the Drawings, minor deviations will be allowed, subject to prior Approval.

A09.3.8.12. Where pipes pass through walls and floors, steel pipe sleeves shall be provided to allow free axial movement of the pipes. Sleeves passing through walls shall be of sufficient length to fully enclose the pipe, from one side of the finished wall to the other side. Sleeves passing through floors shall protrude at least 50 mm above and below the finished floor and soffit to enclose the pipe.

A09.3.8.13. All pipes passing through the roof shall be provided with at least mm lead flashing sandwiched between the layers of waterproofing roofing membrane, and secured to the pipe with a galvanized spring clip.

A09.3.8.14. Where pipes pass through water-containing chambers, puddle flanges of Approved design shall be provided.

A09.3.8.15. Accessible pipes shall be flanged or union connected in sections of three nominal lengths for dismantling. Embedded pipework shall be in straight lengths as far as possible. Pipes with screwed joints shall be installed with hexagon unions at suitable positions for easy removal of equipment.

A09.3.8.16. All pipe installations shall be provided with removable sections to facilitate pipe-cleaning operations.

A09.3.8.17. Pipework shall rest freely upon supports and be carefully aligned prior to final connection.

A09.3.8.18. All pipes on straight runs shall be lined up with facilities for pipes to be rotated for the process of welding joints to avoid welding from the bottom as far as possible.

A09.3.8.19. Site welding shall be applied with pipework unrestrained and each joint hydraulically tested at 1.5 times working pressure plus 350 kPa for 60 minutes without loss of pressure followed by application of appropriate protective coating, both internally and externally, prior to final installation.

A09.3.8.20. During storage, all pipes shall have end covers fitted to prevent the ingress of any unwanted particles or waste.

A09.3.8.21. During installation, all open ends of pipes shall be blanked off with blank flanges or pipe caps. These shall be removed only immediately prior to connecting to adjacent sections. As soon as pipes have been installed, all open ends shall be covered to prevent entrance of materials that would obstruct the pipes. Covers shall be left in place until removal is necessary for completion of the installation.

A09.3.8.22. Damage to coatings or linings during material transport or handling on Site shall be repaired to the Engineer’s satisfaction before installation of the pipework and fittings commences.

A09.3.8.23. The Engineer reserves the right to reject any material deemed to be unsuitable for installation and such material shall be removed from the Site and be replaced with approved material at no extra cost to the Employer.

A09.3.8.24. Steel welded fittings shall be of the same weight as the piping with which they are to be used. Long radius welded elbows shall be used at changes in the direction of the pipework. Welded tees shall be used for branc hes of the same size as the main pipe. Long radius reducing elbows shall be used at pumps. Reducing outlet tees shall be used for branches of smaller size than main pipe. Where the branch size is three or more pipe sizes smaller than the main pipe, steel gussets to provide full pipe strength shall be used. Where a branch is connected to screwed piping, a steel welded threaded socket shall be used. Eccentric welding reducing fittings shall be used at changes in pipe size for horizontal piping, with top level for water piping.

A09.3.8. Supports

A09.3.9.1. Unless otherwise specified or indicated, all brackets, stays, frames, fixed and roller supports and hangers necessary to carry and support all pipes and valves shall be provided.

A09.3.9.2. Generally supports shall be spaced. Unless otherwise specified, pipe supports shall be provided at interval in accordance with the following tables.

Steel pipe size (mm)	Maximum intervals for vertical runs (m)	Maximum intervals for horizontal runs (m)
15	2.5	1.8
20-25	3	2.5
32	3	2.7
40-50	3.6	3
65-80	4.5	3.6
100	4.5	4
150 and above	5.5	4.5

Cast iron and ductile iron pipe size (mm)	Maximum intervals for vertical runs (m)	Maximum intervals for horizontal runs (m)
All	3	1.75

Copper pipe size (mm) (Hot and cold water)	Maximum intervals for vertical runs (m)	Maximum intervals for horizontal runs (m)
22 and below	1.8	1.2
28-35	2.4	1.8

42-67	3	2.4
76 and above	3.7	3

Copper pipe size (mm) (Refrigerant)	Maximum intervals for vertical runs (m)	Maximum intervals for horizontal runs (m)
15 and below	1.2	0.9
22-28	1.8	1.2
35 and above	2.4	1.5

UPVC or ABS pipe size (mm)	Maximum intervals for vertical runs (m)	Maximum intervals for horizontal runs (m)
20 and below	0.8	0.6
25-32	1.1	0.9
40-80	1.4	1.2
100-150	1.8	1.2

A09.3.9.3. Where hangers and/or supports are provided for insulated chilled water pipes, a segmental section of hardwood or high density phenolic insulation approximately 100 mm long shall be inserted, the outer diameter being identical to that of the insulated pipe and the ends thereof facing tight the pipe.

A09.3.9. Hangers

A09.3.10.1. Hangers rods of steel, threaded and fitted with two removable nuts at each ends for positioning rod and hanger and locking each in place shall be provided.

A09.3.10.2. Secure hangers from metallic inserts cast into concrete. When these inserts are not available, attachment by anchor bolts to be placed with fast setting high strength grout shall be used.

A09.3.10.3. Supports and hangers shall be placed as close as possible to joints. When hangers or supports are not within 300 mm of branch line fitting, additional hangers or supports shall be provided at the fitting.

A09.3.10. Welding

A09.3.11.1. Steel piping shall be mill-bevelled on both ends before welding, bevelled to 37.5°. Weld spacing on all butt welds shall comply with the following table.

Nominal pipe wall thickness (mm)	Spacing (mm)	Bevel angle (°)
6.35 or less	3	37.5
6.35 to 19.5	5	37.5

A09.3.11.2. Backing rings shall be used on all butt-welded joints

A09.3.11.3. Before starting any welding, all corrosion product and other foreign material from surfaces to be welded shall be removed by scraping, brushing, chipping and swabbing.

A09.3.11.4. Welding process: welding shall be carried out by either manual shielded metallic arc process or automatic submerged arc process using direct current. Welding procedure specifications shall be submitted for Approval.

A09.3.11.5. Welding operation: Electrodes, voltage, current, thickness and number of passes or beads, shall be as previously specified. After deposition, each layer of weld metal shall be cleaned to remove all slag and scale by wire brushing and grinding and chipped where necessary to prepare for deposition of the next layer. Welded reinforcement shall be not less than 1.6 mm not more than 3.18 mm above the normal surface of sections being welded. Reinforcement shall be crowned at centre and tapered on each side of surfaces being jointed. Exposed surfaces of weld shall present workmanlike appearance and be free of depressions below surface of jointed members.

A09.3.11.6. Weld metal shall be thoroughly fused with base metal at all sections of weld. Penetration of weld shall include unbevelled portion and extend to inside walls of pipe.

A09.3.11.7. Inspection: All welds shall be inspected visually and non-destructively by the Engineer. The Engineer reserves the right to order at random the examination of 2 % of the number of the welded joints for ultrasonic test by an independent firm nominated and paid by the Contractor. Should any one of the above welds prove faulty in materials or workmanship, further test of welds will be ordered up to a total of 4 % of the welded joints. If the number of welds failing the tests within the above 4 %, it is sufficient to suggest that an operative is not consistent in standard, the Engineer may order any number of that welds to be removed and rectified at no extra cost to the Employer.

A09.3.11. Jointing

A09.3.12.1. Pipes shall be cut in a neat manner without damaging the pipe. Unless otherwise approved by the Engineer, cutting shall be done with an approved type of mechanical cutter. Wheel cutters shall be used only when practicable. Pipe ends shall be reamed to remove burrs.

A09.3.12.2. Flanges and unions shall be face true. Flanges shall be provided with approved gaskets and made square and tight.

A09.3.12.3. Screw joints shall be made with tapered threads properly cut. Joints shall be made tight with a stiff mixture of litharge and glycerin, or polytetra fluoroethylene tape, or other approved thread joint compound applied to the male threads only. Not more than three threads shall show after the joint is made up.

A09.3.12.4. Flanges and unions shall be faced true. Flanges with approved gaskets shall be provided and made square and tight. Union or flange joints shall be provided in each line immediately preceding the connection to each place of equipment or material requiring maintenance such as coils, pumps, control valves, and other similar items.

A09.3.12. Protective coating

A09.3.13.1. Buried steel pipes shall be protected against corrosion by treating with two coats of good quality bituminous paint and fully wrapped with an Approved weatherproof tape before laying.

A09.3.13.2. Under special circumstances, such as in ground containing industrial wastes, refuse, ashes, clinker, or in aggressive water-logged clays, additional external protection shall be provided.

A09.3.13.3. Where buried metallic pipes cross the route of the railway, the pipework shall be electrically continuous and double half-wrapped with an approved electrical insulating tape.

A09.3.13. Cleaning

A09.3.14.1. For buried ductile iron pipes bituminous coating against corrosion shall be provided for the pipes and joints where steel is used for bolts and nuts.

A09.3.14.2. Where copper pipework is required to be chromium plated, such pipework shall be sent to a specialist for plating after all pulled bends and soldered joints are completed.

A09.3.14. **Testing**

A09.3.15.1. At Manufacturer's factory, samples of pipes and fittings shall be tested and certified to the relevant IS. Test certificates shall be submitted for each type of pipe and fitting to the Employer.

A09.3.15.2. All pipework, except chilled water pipe which is specified below, including valves and fittings shall be hydrostatically pressure tested to 1.5 times the duty head of the system or 1.5 times the closed delivery valve pressure of the pump, whichever is the highest. The pressure shall be held for a minimum period of 24 hours.

A09.3.15.3. The Contractor shall perform hydrostatic testing of all piping. Preliminary tests shall be carried out to demonstrate that the work is satisfactory. The Engineer and all authorities having jurisdiction shall be notified in ample time to be present for final testing of all piping. Testing shall be carried out before insulating or concealing any piping takes place. Defects disclosed by tests shall be repaired and the complete test repeated. Tests shall be carried out in stages if so ordered by the Engineer to facilitate work of others. Use of wick in tightening leaking joints is not permitted.

A09.3.15.4. Unless otherwise specified, chilled water piping shall be tested hydrostatically to 1553 kPa. Tests shall be for a two hours duration, during which time piping shall show no leaks and during which time no sealing of leaks shall be permitted. Equipment not capable of withstanding test pressures shall be isolated. Blind flanges, bypass valves and piping shall be used as required during testing.

A09.3.15.5. Refrigerant pipework when completed shall be pressure tested by nitrogen gas in two or more steps up to 28 bar and maintained for at least 24 hours. Prior to charging any additional refrigerant as necessary into the system, it shall be vacuum dried. A vacuum test of 1 mm of mercury shall be applied to the pipework and held for 8 hours. The vacuum shall not rise beyond 2 mm of mercury during the 8 hour test.

DATA SHEET FOR PIPES AND FITTINGS FOR ECS	
Pipes	
Up to NB150 mm	As per specification
NB 150 mm – NB 200 mm	As per specification
NB 200 mm And Above	As per specification

Flanges	
Type	As per specification
Material	Mild Steel
Thickness	Suitable For Class – 2 Pressure
Application	Will be Used On All Equipment Which Is Required To Be Isolated Or Removed For Service / Maintenance
Fittings /Bends	As per specification
Nuts / Bolts	Hexagonal Carbon Steel,
Gaskets	6 mm Thick, With Good Mechanical Strength And Fire Rated
Test Pressure	As per specification
The Chilled Water Line Will Be Pressure Tested Before Insulation	
Pipes Passing Thru Any Building Structure Will Pass Thru Pipe Sleeve. Thickness Of Pipe Sleeve will not Be less Than The Thickness Of Passing Pipe Itself.	
Pipe Entering Any Equipment Will Be Protected By The Rubber Grommet or Any Such Material	
Design Velocity	
Pipe	
Condenser Line	3 Mtr / sec
Chiller Line	3 Mtr / sec
Hanger And Supports	
Pipe Dia –mm	
Material	Structural Steel
Up to 12 mm	1200 mm Spacing
20 mm – 25 mm	1800 mm Spacing
30 mm – 150 mm	2400 mm Spacing
Above 150 mm	3000 mm Spacing
For Insulated Pipe Accessories / Drain Valves The Connections Will Be Long Enough Such That The Required Insulation Can Be Carried Out On The Main Pipe	
Insulation Will Be Done In Two Halves For Easy Removal With Effecting Adjacent Insulation	

Section A10: Pipeline fittings

TABLE OF CONTENT

A10.1 General

A10.1.1. This Section specifies the manufacture and installation of globe valves, gate valves, check valves, butterfly valves, motorized valves, gauge cocks, automatic air valves, strainers, dirt pockets, stopcocks, pressure reducing valves, double regulation valves, safety and relief valves, thermostatic mixing valves, UPVC valves for flushing water, drain cocks, ball float valves, safety and pressure relief valves, escutcheons, thermometer, pressure gauges, flow measuring elements, vortex inhibitors, pipe sleeves, expansion loops, expansion joints, pipe anchors, pipe guides, gaskets for pipe separation, access pipes, traps, water – closet connectors and fresh air inlets.

A10.1.2. All valves, taps and cocks shall be of the types and working pressures suitable for the systems to which they are connected. Valves shall be rated to withstand the system hydraulic test pressure.

A10.1.3. Brass, bronze or cast iron valves shall generally be of 16 bar pressure rating (working pressure) type and UPVC valves of 10 bar. In addition, all valves at discharge side of transfer water pumps shall be of minimum 16 bar pressure rating.

A10.1.4. Where valves are provided at the discharge side of 2 or more pumps, each valve shall be so selected to withstand effectively the anticipated system pressure under the worst case scenario.

A10.1.5. All valves shall comply with relevant International Standards or Indian Standards in respect of tests and working pressures, dimensions and materials of construction.

A10.1.6. Wheelhead valves shall be arranged for clockwise operation of the handle to close the valve.

A10.1.7. Screwed valves shall have taper threads

A10.1.8. Connections shall be made between each valve and the adjoining pipework or equipment with flanges for 65mm size pipework and above. Flanges shall be selected to suit working pressure and temperature.

A10.1.9. Screwed connections shall be made between each valve and the adjoining pipework or equipment for 50 mm size pipework and below. A union shall be fitted on each side of all screwed valves.

A10.1.10. All valves shall be suitably located in accessible positions for operation and maintenance purposes.

A10.1.11. All drain outlets and manual air vents shall have connection pipes leading to the nearest drain.

A10.1.12. Valve packing shall be suitable for the service intended. Valve packing consists of asbestos or asbestos based materials shall not be used.

A10.1.13. Valves of identical make, size, type and duty shall be fully interchangeable.

A10.1.14. Inverted mounting of valves shall not be permitted without prior Approval.

A10.1.15. All valves provided for manual operation shall have a handwheel or other suitable device which shall be fixed to the valve. Handwheels shall be rotated clock-wise to close the valves and shall be clearly marked with the words "OPEN" and "CLOSE" and arrows pointing in the appropriate directions. The rims of handwheels shall be machined to a smooth finish. All handwheels which may be dangerously hot to touch when the system is in use shall be provided with an Approved heat insulation on the rim and spokes.

A10.2. Quality control

A10.2.1. Material and workmanship shall be in accordance with the latest edition of the following standards and codes, and the materials shall be certified by the standard organisation.

BSEN 593 : Butterfly Valves
BS 7350: Double Regulating Globe Valves and Flow Measurement Devices for Heating and Chilled Water Systems
IS 210: Grey iron castings-specification
IS 318: Specification for leaded tin bronze ingots and castings
API 594: Check valves-Flanged, Lugged, Wafer and Butt-welding
API 598: Valve inspection and testingAPI 609: Butterfly valves – Double-flanged, Lug-and-Wafer type
JIS B302:

A10.3. Technical and installation requirements

A10.3.1. Globe Valves

A10.3.1.1. Generally, globe valves shall be used on service pipelines where regulation is required, and shall be supplied and fitted in positions indicated on the Definitive Design Drawings.

A10.3.1.2. The bodies shall be of an even thickness throughout, clean and free from scale and flaws. Valves up to and including 50 mm nominal bore shall have bronze bodies and valves of 65 mm bore and larger shall have cast iron bodies. No material used shall be susceptible to dezincification.

A10.3.1.3. Globe valves are used for circuit regulation and shall have characterised plug discs. The discs shall be free to rotate, readily removable from the valve stem and renewable. Discs may be manufactured proprietary composition type materials if approved by the Engineer.

A10.3.1.4. Valves may have packed stuffing boxes or be fitted with ’O’ rings.

A10.3.1.5. Valves up to and including 50 mm nominal bore shall have taper screwed ends, valves of 65 mm nominal bore and larger shall have flanged connections.

A10.3.1.6. Regulating valves shall be fitted with a lockable spindle to limit the proportion open once regulation is complete.

A10.3.1.7. Bronze globe valves shall be rising stem pattern. Cast iron globe valves shall be outside screw rising stem type.

A10.3.2. Gate Valves

A10.3.2.1. Generally, gate valves shall be used on service pipelines where isolation of plant, equipment and system circuits is required and shall be fitted in the locations indicated on the Definitive Design Drawings.

A10.3.2.2. The bodies shall be of an even thickness throughout, clean and free from scale and flaws. Valves up to and including 50 mm bore shall be bronze, 65 mm bore and larger shall be cast iron. No material used shall be susceptible to dezincification.

A10.3.2.3. Valve wedges may be of cast iron, bronze, nickel alloy or stainless steel. Cast iron wedges shall have bronze trims and seating. Wedges shall be renewable and free to rotate on the valve spindle.

A10.3.2.4. Valves may have packed stuffing boxes or alternatively may be fitted with ’O’ rings.

A10.3.3.1. Bronze gate valves shall have non-rising spindles. Cast iron body gate valves shall be outside screw rising stem type.

A10.3.3. Balancing Valves

10.3.4.1 The balancing valves shall be capable of measuring, regulating and isolating the flow.

A10.3.4.2 The balancing valves up to 50 mm dia shall be of gunmetal body screwed type and 65 mm dia and above shall be cast iron body double-flanged type confirming to BS 7350, IS 210, IS 318 or equivalent standard.

A10.3.4.3 All internals shall be non-corrosive material preferably of brass or stainless steel.A10.3.4.4 The port opening shall permit precise regulation of flow rate, by accurately measuring the pressure drop across the port.

A10.3.4.5 The valve shall be complete with two ports for connections to a mercury manometer, to measure the pressure drop, as well as drain port.

A10.3.4.6 The spindle shall have a shielded/concealed locking screw to avoid the tempering of the setting after balancing.

A10.3.4.7 The valves must have easily accessible pressure drop measuring facility.

A10.3.4.8 The balancing valve shall have indication of number of turns on hand wheel preferably digital type.

A10.3.4.9 The balancing valve shall be used in liew of butterfly / gate / globle / regulating / flow measurement valves and shall be suitable at 16 bar pressure.

A10.3.4.10 The valves shall have a locking arrangement to set the valve at the desired position.

A10.3.4.11

Disc	SS410/Brass
Seal	EPDM
Handwheel	Mild Steel/Nylon
Stem	SS410

A10.3.4. Flow Measurement Valves

A10.3.4.1. Flow measurement valve sets shall comprise a screwed or flanged gate valve close-coupled to a flow measurement device.

A10.3.4.2. Sets up to DN50 size shall be screwed end valves and threaded nipple type carrier with integral orifice ring. Sets DN65 size and above shall be flanged and include an orifice plate and carrier with mating flange. Sets shall be used for measurement and isolation in conjunction with a double regulating valve.

A10.3.5. Flow Measurement Variable Orifice Double Regulating Valve

A10.3.5.1. Double regulating valves as described shall additionally be provided with 2 No. double seated pressure test valves for flow measurement in conjunction with a double regulating valve used in a balancing application.

A10.3.6. Flow Measurement Fixed Orifice Double Regulating Valves (FODR Valves)

A10.3.6.1. FODR valves up to DN50 shall be as for double regulating valves to BS 7350 or other equivalent standard directly coupled to a flow measurement device comprising male/female threaded nipple type carrier with integral orifice ring and 2 No. double seal pressure test valves.

A10.3.6.2. FODR valves DN65 and above shall be cast-iron double regulating valves to BS 7350, or other equivalent standard with flanged connections.

A10.3.6.3. The flow measurement device shall comprise a single piece stainless steel square edged orifice plate carrier with 2 No. double seal pressure test valves, integral orifice to fit between the valve outlet flange and mating flange.

A10.3.6.4. Low flow rate commissioning sets shall comprise bronze double regulating globe valve with bronze stem, slotted parabolic disc and screwed ends, close-coupled to a bronze carrier with integral fixed orifice and 2 No. double seal pressure test points.

A10.3.6.5. Butterfly valve commissioning sets DN65 to DN300 shall comprise cast-iron wafer semi-lugged valves with stainless steel shaft, aluminium bronze disc, nitrile liner and gear operated double regulating properties close-coupled to fixed orifice nickel-plated cast-iron measuring station, with 2 No. double seal pressure test points.

A10.3.7. Check Valves

A10.3.7.1. Check valves shall be supplied and fitted in the locations indicated on the Definitive Design Drawings. Care shall be taken to ensure that the valves supplied are suitable for installation in the plane required as per data sheets. Check valves shall not be installed in vertical pipes with a downward fluid flow.

A10.3.7.2. Check valves up to 65mm shall be of bronze/gun metal body with renewable nitrile rubber faced disc and screwed-in cap with ends screwed taper thread.

A10.3.7.3. Check valves 75mm and above shall be of cast iron body.

A10.3.7.4.

Ref standard	Designed and tested as per API594 and API598 or equivalent standard.
Pressure Rating	16 bar
Type	Dual plate wafer type
Seal	BUNA-N or Metal
Hinges and stop pin	SS410
Spring	SS316

A10.3.8. Butterfly Valves (Non-Motorised)

A10.3.8.1. Valves of DN40 and larger shall be of cast iron/ductile iron body and arranged to be fixed between pairs of mating flanges (wafer body) with interconnecting long bolts.

A10.3.8.2. Valve stems shall be of stainless steel with either 'O' ring type seals or non-asbestos material packed glands.

A10.3.8.3. Not used

A10.3.8.4. Valve discs shall be either stainless steel or aluminium bronze and shall be machined to give tight shut off against the valve seat. Valves may contain proprietary latex based materials to ensure that a good seat is obtained. Where such materials are utilised they shall be well proven in use and fully bonded.

A10.3.8.5. Valves shall be supplied with graduated indicator plates to show disc position.

A10.3.8.6. Generally valves up to and including DN150 shall be lever operated and valves in excess of DN150 shall be provided with gear operation.

A10.3.8.7. Not used

A10.3.8.8. Not used

A10.3.8.9.

Pressure Rating	16 Bar
Ref Standard	IS13095, BS5155,API609, BSEN593, JIS B302, MSS-SP67
Construction	Single Piece Ribbed Construction And Flangeless Wafer
Body	Cast Iron/Ductile Iron
Disc	Aluminum Bronze / SS304 / SS316
Seat	Nitrile Rubber Bonded On Bakelite Hard Back / EPDM
Shaft	SS304/SS410

A10.3.9. Ball Float Valves

A10.3.9.1. Level controllers size 15mm shall be brass bodied float operated valves of the diaphragm type with discharge component to effectively prevent back-siphoning of water, all in accordance with BS 1212 Part 2. Copper floats shall be to BS 1968, and plastic floats to BS 2456 or equivalent.

A10.3.9.2. Valves DN20 to DN30 shall be gunmetal bodies double seat balanced equilibrium type of full bore pattern with inlet screwed end.

A10.3.9.3. A stopcock shall be fitted on the inlet to all ball float valves.

A10.3.9.4. Ball float valves of the delayed action type shall incorporate an equilibrium type ball valve with the float operating in an auxiliary chamber within the storage tank, cooling tower, etc. A second float below the base of the chamber shall operate a quick-operating valve, which shall provide open/shut control. Such ball valves shall be fitted where indicated on the Definitive Design Drawings.

A10.3.9.5. Ball float valve installations shall be complete with water stilling pipes to minimize the effect of the water inflow on the operation of the floats and the level controllers.

A10.3.10. Ball Valves

A10.3.10.1. Ball valves up to DN50 shall be copper alloy bodies of DZR brass or as per manufacturing standard, have an inhibited brass body with chrome coated ball plug and valve stem, and PTFE seat and seals.

A10.3.10.2. Valves shall be 1/4 turn lever handle operated.

A10.3.10.3. Valves DN65 and above shall be cast iron.

A10.3.11. Foot Valves

A10.3.11.1. Foot valves with inlet bolted strainer shall be fitted on all pump suction dip pipes.

A10.3.11.2. Valves shall be fitted with a leather flap and shall be screwed up to DN50 and flanged DN65 and above.

A10.3.12. Three-way Escape Valves

A10.3.12.1. Three-way escape (diverting) valves as per datasheet shall be prrovided.

A10.3.12.2. Seat arrangement shall be that closure of one outlet port occurs when the alternate outlet port is opened. Clockwise hand wheel operation shall open the vent port.

A10.3.13. Strainers

A10.3.13.1. Strainers shall be 'Y' pattern, unless otherwise indicated, suitable for 16 bar pressure and service of the piping system and of the same nominal bore as the pipeline in which they are to be installed.

A10.3.13.2. Strainers shall be screw or flanged connected to suit the isolating valves adjacent to, and on the 'dead' side of which they shall be installed.

A10.3.13.3. Strainers 15-300mm for use up to 120°C shall have upstream and downstream self-sealing test points incorporated and two blank tapped points.

A10.3.13.4. Baskets/screens shall be readily accessible for removal with adequate clearances for inspection and clearing.

A10.3.13.5. Baskets/screens shall be of specified sheet material with perforations recommended by the manufacturer for the service application.

A10.3.13.6. Baskets/screens shall be cleaned with solvent after pipeline pre-operational cleaning and shall be again thoroughly cleaned before issue of a Completion Certificate.

A10.3.13.7. Strainers for cold service size DN15 to DN40 shall be gunmetal body, screwed ends, with stainless steel screen, non-ferrous cap and non-asbestos cap gasket.

A10.3.13.8. Strainers DN50 to DN200 shall be cast iron flanged body, with stainless steel strainer screen, cast iron cap, asbestos-free reinforced non-stick cap gasket. The cap shall be complete with 20mm drain valve fitted with hose union.

A10.3.13.9. Strainers DN250 and above shall be cast steel flanged Y-type with stainless steel screen and scantlings as for DN200.

A10.3.14. Thermoplastic Valves

A10.3.14.1. Thermoplastic valves only shall be installed in ABS and uPVC pipework systems.

A10.3.14.2. Solvent weld end valves shall be provided for sizes up to DN50. DN80 size valves shall be flanged.

A10.3.14.3. Pipelines requiring regulation shall be fitted with 'B' grade diaphragm valves.

A10.3.14.4. Pipelines requiring shut-off provision only shall be provided with ball valves with plain ends for solvent weld jointing in sizes DN15 to DN80 inclusive.

A10.3.14.5. Foot valves and strainers in thermoplastic pipework systems shall be PVC ball foot valves and strainers for solvent welding.

A10.3.15. Stopcocks

A10.3.16.1. Stopcocks for fresh water systems shall conform to BS1010 Part 2 or equivalent standard and the materials for constructing the stopcock shall be non-dezincifiable type. They shall generally be able to withstand a working pressure of 16 bar.

A10.3.16. Drain Valves

A10.3.17.1. Drain valves shall be provided at the bottom of every riser and at all low points within the water systems to enable full draining down of the entire system.

A10.3.17.2. Drain valves shall comply with BS 2879, be screwed end, solid wedge disc, inside screw, non-rising stem, screwed in bonnet lock shield type bronze gate valves with hose union connection.

A10.3.17.3. Extended drain lines shall be of the same size as the drain valves.

A10.3.17.4. Drain valves shall be of sizes indicated below:

Main Pipe Size (DN)	Drain Valve Size (DN)
Up to 25	15
32-100	20
100-300	32
300-600	50

A10.3.17. Drain Cocks

A10.3.17.1. Drain cocks shall be gunmetal or bronze, gland pattern with screwed female inlet, BSP taper thread, hose union outlet and complete with operating wrench.

A10.3.18. Gauge/Test Cocks

A10.3.18.1. Gauges and other instruments shall be fitted with a gauge cock between the instrument and the service pipe.

A10.3.18.2. Gauge cock bodies shall be bronze construction with polished finish and parallel threads.

A10.3.18.3. Gauge cocks for use with chilled water; condenser cooling water and cold water shall be of the straight pattern, ground plug type with lever handle.

A10.3.19. Automatic Air Eliminator Valves

A10.3.19.1. Connections to the service pipe shall be made at the highest point to ensure complete venting. Valves shall be mounted so that the inlet connection is in an exact vertical plane. A lock shield valve shall be provided between service pipe and automatic air release valve. The highest point shall include both ends of Station Concourse plantroom pipework and also Auxiliary Building plantrooms pipework.

A10.3.19.2. Valves for water systems may have bodies of brass, gunmetal or malleable iron, non-ferrous or stainless steel floats and guides, and non-corrodible valves and seats.

A10.3.20. Vortex Inhibitors

They shall be designed in such a way as to prevent the pump from creating a vortex and drawing air when the pump is running under a low suction head.

A10.3.21 Expansion Tank

The chiller system shall include for a pressurised closed type expansion tank of capacity as per BOQ. The tank shall be rated for a pressure 10bar and a temperature range between 5 °C to 50 °C. The tank shall be fitted with a safety valve

The tank shell shall be heavy gauge carbon steel and the replaceable membrane shall be of butyl/EPDM material.

A10.3.21. Not Used

A10.3.22. Vacuum Degasser

A10.3.19.3. The vacuum degasser shall be of a solid and a robust construction. It should work on pressure differential deaeration principle. It shall be installed as a bypass to the main CHW line and shall be used for removal of dissolved gases from water to make the water absorptive in order to prevent corrosion as well as remove air locks from the most distant ends of the CHW pipeline. The Degasser shall be of Plug & play type & shall be of automatic operation. The degasser shall be capable of refilling the CHW pipeline with degassed water to compensate the volume of vented gases. The Deagasser shall be able to switch itself off when the pipeline achieves desired Pressure & degassed levels of water. It should be with a Multi-stage Centrifugal pump. The Degasser shall be of Carbon Steel with a Brass Automatic Airvent. It should degas the volume from 150 to 300m3 holding capacity.

A10.3.23. Dirt Separator

A10.3.23.1. The Dirt separator shall be of a solid and robust construction (Mild Steel). All the connections, fittings and heads shall be of carbon steel. The Dirt separator shall be capable of removing solid particles upto 20 microns from water. All connections, fittings and heads shall be of carbon steel. The medium used to remove dirt shall be manufactured of Steel Tube & copper wire or stainless steel depending upon the quality of water to be passed through it. This medium should be non clogging in nature. The flow should not be obstructed by the dirt collected. Centrifugal action for Dirt separation is not acceptable. A brass Drain valve should be present to remove the accumulated dirt without the need of shutting down the operation of the system. The Dirt Separator shall be insulated depending upon its location (outdoor or indoor).The pressure drop on account of the air and dirt separator shall not exceed the values below

	For Max velocity of 1.5m/s	**For Max velocity of 3m/s**
Connection (DN) of Dirt Separator	**ΔP @ Max. Flow (kPa)**	**ΔP @ Max. Flow (kPa)**
50	3.0	11.8
65	2.7	11.6
80	2.9	12.4
100	3.7	14.6
125	4.2	16.8
150	4.9	19.4
200	5.8	23.1
250	6.9	27.7
300	7.7	31.0
350	7.8	31.0
400	8.4	34.0
450	10.0	39.0
500	11.0	43.0
600	12.0	47.0

A10.3.23.1. For connections larger than DN 600, the contractor must provide the pressure drop specifications in his submittal for approval.

A10.3.24. Air & Dirt Separator

The Air and Dirt separator shall be of a solid and robust construction (Mild Steel). It shall be able to remove free air and microbubbles as well as remove solid particles upto 20 microns from water at Velocity between 2-3m/s. Removal of Air & dirt shall be through coalescence. The unit shall be able to condition the water to make it highly absorptive at all points in the system .This ensures that microbubbles can no longer exist at any point in the system. All connections, fittings and heads shall be of carbon steel. The medium used to de-aerate and remove dirt shall be manufactured of Steel Tube & a mesh made of copper wire. This medium should be non clogging in nature. An automatic air vent of atleast 100mm free area to be connected at the top for the release of the air separated from the water. The flow should not be obstructed by the dirt collected. A Drain valve should be present at the bottom to remove the accumulated dirt without the need of shutting down the operation of the system. The Air & Dirt Separator shall be insulated depending upon its location (outdoor or indoor). The pressure drop on account of the air and dirt separator shall not exceed 21kPa at maximum flow of the chilled water system. The performance of the air & Dirt Separator shall be confirmed by test report.

A10.3.25. Motorized Valve Operators

A10.3.25.1 Mount motorized valve operators at factory or at Site under manufacturer's supervision.

A10.3.25.2 Provide a handwheel for each valve operator, which shall automatically de-clutch when motorized valve operator is functioning.

A10.3.25.3 The motorized valve operator shall be capable of operating in any valve mounting altitude and capable of being mounted either in line or transverse to the pipeline.

A10.3.25.4 The motorized valve operator shall be bolted directly to the butterfly valve top without the use of special brackets, linkages or couplings if butterfly valves are used.

A10.3.25.5 Where motorized valve operators are exposed to weather, provide a 0.6 mm G.I. or aluminium removable housing to the Approval of the Engineer or provide IP67 rated actuators.

A10.3.25.6 Motorized valve operator shall be totally enclosed with no external moving parts. The actuator shall be of the rack and pinion type or rotary type providing constant output torque.

A10.3.25.7 Motorized valve operator shall operate on 24 / 120 / 240 V as per system design requirements. Motorized valve operator shall consist of motor, magnetic motor controller, control circuit transformer, built-in reversing contactors, opening and closing torque and limit switches, built-in open-close-stop momentary contact pushbuttons and open-close position indicating lights. Terminal posts shall also be provided for field wiring of remote momentary contact open-close-stop pushbuttons and open-close position indicating lights. All components shall be factory prewired in single enclosure.

A10.3.25.8 Motor shall be of high speed and high torque type, of adequate capacity, specially suitable for valve operation. Motor winding insulation shall be to IEEE standard class B. Provide built-in thermal overload protection. Closing time of all motorized valves shall be set with an adjustable timer control as per system design requirements.

A10.3.26. Motorised Butterfly Valve

A10.3.26.1 Valves of DN40 and larger shall be of cast iron / ductile iron body and arranged to be fixed between pairs of mating flanges (wafer body) with interconnecting long bolts.

A10.3.26.2 Valve stems shall be of stainless steel with either 'O' ring type seals or non-asbestos material packed glands.

A10.3.26.3 Not used

A10.3.26.4 Valve discs shall be either stainless steel or aluminium bronze and shall be machined to give tight shut off against the valve seat. Valves may contain proprietary latex based materials to ensure that a good seat is obtained. Where such materials are utilised they shall be well proven in use and fully bonded.

A10.3.26.5 Valves shall be supplied with graduated indicator plates to show disc position.

A10.3.26.6 Manual operation facility shall also be provided for the valves. Generally valves up to and including DN150 shall be lever operated and valves in excess of DN150 shall be provided with gear operation.

A10.3.26.7 Motorized butterfly valve for chillers, cooling towers shall be 2 positions ON/OFF type Butterfly valve with standard train. The valve shall be controlled by an electric actuator mounted directly on the valve. The actuator shall have a reversible synchronous motor and generate the desired stoke by gear train. It shall be suitable for hook up to any major BMS.

A10.3.26.8 Actuator

- Each actuator shall have current limiting circuitry incorporated in its design to prevent damage to the actuator.
- Actuators shall provide the minimum torque required for proper valve close-off against the system pressure for the required flow.
- Two-position or open/closed actuators shall accept 24 / 120 / 240 Vpower supply as per system design requirements and shall be UL / CS / CSA marked. Butterfly isolation and other valves, as specified in the sequence of operations, shall be furnished with adjustable end switches to indicate open/closed position or be hard wired to start/stop the associated pump or chiller

A10.3.26.9

Actuators	Two position or Open/Closed type shall accept 24/120/240 Volt power supply.
Valve Type	On/Off Type and shall be Controlled by an Electric Actuator & BMS compatible.
Pressure Rating	16 Bar
Ref Standard	IS13095, BS5155,API609, BSEN593
Body	Cast Iron/Ductile Iron
Disc	Aluminum Bronze / SS304 / SS316
Seat	Nitrile Rubber Bonded On Bakelite Hard Back / EPDM
Shaft	SS304/SS410

A10.3.27. **Pressure Independent Control valve (AHU and FCU)**

A10.3.27.1 Valve shall be electronic, dynamic, modulating, 2 ways, control device. Maximum flow setting shall be adjustable to 51 (AHU) / 41 (FCU) different setting within the range of the valve size. It shall be BMS compatible.

A10.3.27.2 Valve actuator housing shall be rated to IP54. Actuator shall be driven by 24 VDC motor and shall accept 2-10 VDC, 4-20mA, 3-point floating or pulse width modulation electric signal and shall include resistor to facilitate any of these signals. Actuator shall be capable of providing 4-20mA or 2-10VDC feedback signal to control system. Fail safe system to power valve to either open of closed position from any position in case of power failure shall be available Extended LED read – out of current valve position and maximum valve position setting shall be available for AHU PICV.

A10.3.27.3 Fan coil units PICV shall be installed with 3 Nos ball valve (for flow, return and by-pass), Y-strainer, drain hoze connection with pressure temperature meters.

A10.3.27.4 PICV shall comply with following specification

- The PICV valves shall meet the following high performance generic specific criterion: Valves should be pressure independent and should have integral differential pressure control over built in control valve and flow control.
- The valves should have a bonnet for temperature control and diaphragm operated differential pressure controller all built in one valve body.
- Valves should be protected against overload with a safety spring Valves should be inline body type and should be suitable for modulating control at temperatures between -10° and +110° Centigrade
- Valves shall be suitable for Pressure class PN25 Valves body to me made only from Ductile Iron for AHU PICV and Brass for FCU PICV, and surface should be Dual solid painted.
- The diaphragm, sealing and gaskets shall be made from EPDM / HNBR
- The valve seat shall be made from stainless steel for AHU PICV and as per manufacturing standard for FCU PICV.
- The valve should be designed for readjustment of flow rate at site without removal of actuator.
- The pressure drop on the flow control spring / throttle should not exceed 60kPa.

The PICV for FCU air terminal units with shall have the following criterion with respect to the above mentioned:

- The valve should have integral spring and diaphragm arrangement for differential pressure control.
- Valve should be capable of operating under maximum differential pressure of 400 KPascal.

- The pressure drop on the flow control spring / throttle should not exceed 40kPa.

- The minimum lift on the control valve shall be 10mm and 3 mm resp. Generally PICV valves shall be a single assembly, however, for larger valves to the district cooling plant shall be a differential pressure valve (DPC) and low loss control valve (CV).

- Installation and construction shall comply with below mentioned specification

Stem/ Spindle	Non-rising of stainless steel

Direction of flow	Flow arrow on valve body
Arrangement	Assembled with isolation valves, strainers, drain/hose connection, pressure/temperature plug
Joints	Integrated union joints for valve alignment
Flushing	Bypass, backward & forward to be provided for flushing

)ATA SHEET FOR PIPES AND FITTINGS FOR ECS	
Control Valves	
Construction	
Type	Two Way
Arrangement	Metal To Metal Seating, And Spring Loaded Packing
Flow	Constant Total Flow Throughout Full Plug Travel
Indicator	Easy To Read Valve Position Indicator
Material	Stainless Steel
Body	
Up To 50 mm	Screwed End Connection
Above 65 mm	Flanged End Connection
Packing	Teflon Cones Spring Loaded Self Adjusting
Stem	Stainless Steel
Plug	Stainless Steel / Brass
Seat	Stainless Steel
Test Pressure	10 Kg / cm^2 For Condenser And Chilled Water Line.
Motor Actuator Type	Proportional Acting Type
Motor Actuator Rating	220 V, 50 Hz, AC Supply
Motor Actuator Speed	6 – 8 RPM
Valve Operation	With Room / Return Air Thermostat And Motor Actuator
Valve Application	For Chilled Water Flow Control Of The AHU At Supply / Return Water Temperature As Per Chiller Data (Station wise).

DATA SHEET FOR PRESSURE GAUGE	
Type	Direct Reading
Relevant Codes / Standard	Relevant International Standards
Pressure Gauge Element	Bourdon
Range	0-10 Kg/cm²
Socket Material	SS-316
Movement	SS-316
Process Connection	½ Inch NPT (M) Bottom Connection
Accessories	Snubber : ½ Inch NPT (M) x ½ Inch (F), SS-316
Mounting	With Ball valve
Dial	Round Diameter 100 mm
Color	White Background With Black Print
Bezel Ring	Screwed
Blow out Protection	Back, Disc
Window Material	Toughened Glass
Enclosure	Weather Proof to IP55
Zero Adjustment	Micrometer Pointer
Over Range Protection	130% of Range
Normal Accuracy	± 1% FSD
Tag No.	Tag No To Be Marked On Dial With Black Letter .SS Tag To Be Firmly Attached.

DATA SHEET FOR TEMPERATURE GAUGE	
Type	Direct Reading
Relevant Codes / Standard	Relevant International Standards
Pressure Gauge Element	Bourdon
Range	0-50 ºC
Socket Material	SS-316
Movement	SS-316
Process Connection	½ Inch NPT (M) Bottom Connection
Accessories	Snubber : ½ Inch NPT (M) x ½ Inch (F), SS-316
Mounting	with Ball valve
Dial	Round Diameter 100 mm
Color	White Background With Black Print
Window Material	Toughened Glass
Enclosure	Weather Proof to IP55

Zero Adjustment	Micrometer Pointer
Over Range Protection	130% of Range
Normal Accuracy	± 15%FSD
Tag No.	Tag No To Be Marked On Dial With Black Letter .SS Tag To Be Firmly Attached.
Thermometer Should Be Immersed In The Oil Well, Oil Well Should Be Immersed Into The Water.	

Section A11: Packaged split air-conditioning units/VRV units – NOT USED

Section A12: Fans

TABLE OF CONTENT

A12.1. General

A12.1.1. This Section specifies the manufacture and installation of all ventilation fans as shown on Drawings.

A12.1.2. The fan external total pressure resistance figures specified on the Equipment Schedules and/or Drawings are for guidance and information only and are calculated based on assumed resistance figures of equipment. The exact fan total pressure based on the duct run and the offered equipment shall be carefully checked and re-calculated for each fan before ordering the equipment. Calculation shall be submitted for Approval. No modification to the ductwork system shall be allowed without prior Approval. Any additional cost for the modification of the system (fans, motors, switchgears, cables, panel boards, switchboards, etc.) necessary to meet the specified duties, spatial conditions and the offered equipment shall be provided at no extra cost to the Employer.

A12.1.3. Allowance shall be made for the effects on fan performance of all installation conditions including coils, eliminators, sound attenuator, plenums, enclosures, inlet and discharge arrangements so that actual installed fan performance equals that specified.

A12.1.4. Proprietary bell mouth and wire guard shall be provided for fans without ductwork connection. Bell mouth is not required for propeller fans.

A12.2. Quality control

A12.2.1. Reference Codes and Standards

AMCA Standard 210: Laboratory Methods of Testing Fans for Rating
BS 848: Fans for General Purposes
IS / IS / IEC 60034 for design, performance and efficiency of motors
ISO 5801: Industrial Fans – Performance Testing using Standardized Airways

A12.2.2. Codes and regulations of the jurisdictional authorities.

A12.2.3. All fans, drives and accessories shall be designed, constructed, rated and tested in accordance with the recommendations and standards of AMCA / ISO.

A12.2.4. Fan tests shall conform to the requirements of AMCA Standard 210 or ISO 5801 or to an Approved equal standard.

A12.2.5. Sound ratings shall conform to AMCA standard test code for sound rating of air moving devices or BS 848: Part 2.

A12.3. Technical and installation requirements

A12.3.1. Description

A12.3.1.1. Fans shall have non-overloading characteristic, except for forward curved centrifugal, over their entire operating range. The characteristic curves shall be such that the fan operating point falls between the no flow static pressure and the maximum mechanical efficiency. The fan characteristic shall also be such that for a 15 % increase in total pressure over the specified value, the fan shall deliver not less than 85 % of the specified air volume flow rate. The stability of fan operation shall not be affected under such situation.

A12.3.1.2. All axial flow fans with nominal rating above 7.5 kW shall have a minimum efficiency of 70%. The manufacturer’s best efficient fans shall be selected through manufacturer’ software by engineer in charge during approval.

A12.3.1.3. Each fan unit including motor and drive shall be supplied from the manufacturer as a completely factory-assembled package and all guarantees and test certificates shall be deemed to apply to the entire assembly.

A12.3.1.4. All fans shall be capable of withstanding the pressures and stresses developed during continuous operation at the selected duty. Additionally, all belt driven fans shall be capable of running continuously at 15% in excess of the selected duty speed (As applicable).

A12.3.1.5. Lifting eye/Flanges shall be provided on all centrifugal and axial fans.

A12.3.1.6. All fans shall be statically and dynamically balanced.

A12.3.1.7. All centrifugal fan shafts shall have the ends drilled to receive a tachometer.

A12.3.1.8. Motor speed shall not exceed 1495 rpm unless otherwise specified.

A12.3.1.9. Nominal motor nameplate rating shall be higher than the peak operating power of the selected fan curve for non-overloading characteristic. The motor rating shall be a minimum of 15% higher than the motor operating point at design conditions unless otherwise specified.

A12.3.1.10. All fans and motors offered shall be of minimum vibration and noise level during operation. Should the vibration and noise level be excessive and not within acceptable standards, additional vibration isolation and sound attenuation shall be provided at no extra cost to the Employer to the satisfaction of the Engineer.

A12.3.1.11. All fans are required to be hot dip galvanised/ galvanised.

A12.3.2. Propeller Fans

A12.3.2.1. The impeller shall be designed to give maximum volume with minimum noise level and minimum power consumption and shall be made of steel or aluminium alloy. The hub shall be steel with grey stove epoxy finish or aluminium alloy. The fan shall be complete with anti-vibration mount.

A12.3.2.2. The motor shall be dust and moisture protected to IP54 and of a totally enclosed construction with permanently lubricated ball bearings suitable for running in ambient temperatures of up to 50°C and relative humidity of up to 100%.

A12.3.2.3. Wire guards made of heavy gauge steel wire or rod with all joints and crossings welded and shall be fitted to impeller side or motor side or both where appropriate.

A12.3.2.4. Propeller fans shall be diaphragm mounted on not less than 3mm thick steel mounting plate with stove epoxy grey finishes.

A12.3.2.5. Provided with seal permanently lubricated bearings.

A12.3.2.6. With tip speed not exceeding 17.5m/s

A12.3.3. Axial Flow Fans (Vane/Tube axial)

A12.3.3.1. Provide axial flow, direct drive aerofoil fans as specified on the Equipment Schedules and/or Drawings.

A12.3.3.2. Fan Casing

- Casing shall enclose the motor and impeller.
- Fan casings shall be fitted with matching flanges on the inlet outlet ends with spigots for attachment of flexible connections.
- Inspection doors or sight ports to enable direction of rotation to be established shall be provided.
- Terminal boxes welded/screwed to the casing shall be provided for electrical connection using metallic flexible conduits to fan motor complying with BS 4999: Part 20 for dust and weatherproof conditions.
- Grease nipples shall be brought to the outside of the casing in the most accessible position and fitted with lubrication tube made of copper or other Approved material.
- Gasketed access doors shall be provided in each fan housing or connecting ductwork, suitable for access to adjust or replace blades. For smoke extraction fans, the gaskets shall be suitable for continuous

operation in an air stream temperature of 250 °C for not less than two hours.

A12.3.3.3. Impeller.

- Impellers shall be of die-cast aluminium alloy.
- For hub size of 315mm (dia.) and above, blades shall be manual adjustable without removing the wheel.
- Positive locking shall be provided for securing the impeller blades into the hub. Spun aluminium hub caps shall be fitted.
- The blades shall be counter-balanced and mounted on a thrust bearing for vertically installed fans.

A12.3.3.4. Except smoke extraction fans and unless otherwise specified, drive motors shall be of class F insulation (BS 4999 and BS 2757) totally enclosed type and rated for continuous operation in ambient temperature of 50 °C. Performance and rating shall comply with BS 5000 and IEC 34-1 with protection to IP55. All motors shall be of efficiency class IE-2.

A12.3.3.5. Factory bell mouth shall be provided where no duct connection is required. Fans shall be fitted with bell mouth inlets. Flow cores and bell mouth inlets shall be fabricated in steel and provided with flanges drilled and rigidly bolted to the fans.

A12.3.3.6. Provide wire guards on fan outlet/inlet not connected to ductwork and shall be made freely accessible for maintenance.

A12.3.3.7. Fans shall be provided with mounting feet and spring isolators.

A12.3.3.8. The bearing life of the fan motor assembly shall be of 40,000 hours (L-10 life).

A12.3.3.9. Stationary, curved guide vanes shall be located on the outlet side of the fan to straighten the motion of the air leaving the blades to improve operating efficiency if required.

A12.3.3.10. For smoke extraction fan, adequate clearance shall be provided between blade tips and housing at all points to allow for expansion and contraction over a continuous operation in an air stream temperature range from 0 °C to 250 °C without developing interference to the specified flow capacity. The fabrication/shop drawings shall show the clearance at over a continuous operation in an air stream temperature range from 0 °C to 250 °C as well as any point of minimum clearance in between. The motors in case of smoke extraction fans shall be fire rated for 250°C, 2 hours.

A12.3.4. Centrifugal Fans

A12.3.4.1. Provide forward/backward curved fans as specified on the Equipment Schedules and/or Drawings. Backward curved type shall be non-overloading.

A12.3.4.2. Unless otherwise indicated, centrifugal fans consuming more than 7.5kW at the fan shaft shall be of the backward bladed type having a fan total efficiency not less than 80%. Centrifugal fans with shaft power exceeding 15kW shall be of the aerofoil backward curve type.

A12.3.4.3. Fan Casing

- Fan casing shall be of sheet steel construction adequately stiffened and braced and shall be entirely free from vibration or drumming during normal operation. The steel required to be galvanised / hot dip galvanised.
- All fans with an inlet eye diameter exceeding 300mm shall have a bolted access door on the scroll for access purposes. The size of access panels shall be such as to facilitate cleaning and maintenance of the impeller.
- Drain sockets or holes with copper drain pipe brought out to an accessible point, valved and plugged, shall be provided.

- Fan casings shall be fitted with flanges on the outlet connection suitable for connection of discharge ductwork and flexible connections as shown on the Drawings.
- Where the inlet side of the fan is connected to ductwork, matching flanges for connection of flexible connections shall be provided
- Inspection doors or sight ports to enable direction of rotation to be established shall be provided.

A12.3.4.4. Fan Impellers

- Impellers shall be double inlet, double width or single inlet, single width as shown on the Equipment Schedule and/or Drawings and shall be mounted on substantial hubs.
- Fan impellers shall be backward/forward sloping blades as specified on the Equipment Schedule and/or Drawings.
- Impellers shall be rigidly fixed to solid bright steel shafts adequately sized and proportioned to ensure that the maximum operating speed is not more than 60% of the first critical speed. The shaft shall be protected by reliable anti-rust coating.
- Impellers shall be of steel, electro-galvanized after fabrication (or aluminium where indicated), of riveted or welded construction, with spiders or hubs, of robust design and shall be capable of running continuously at 15% in excess of normal speed.
- All forward curved fans shall be selected for use with speed not exceeding 1200rpm and backward curved fans shall be selected not to exceed 2000rpm, unless otherwise specified.

A12.3.4.5. Unless otherwise specified, drive motors to Class F insulation shall be totally enclosed and rated for continuous operation in an ambient temperature of 50°C. Performance and rating shall comply with IEC 60034. All motors shall be of efficiency class IE-2.

A12.3.4.6. The fan and motor shall be mounted on rigid galvanized steel channel base. Provide slide rails for adjustable mounting of motors.

A12.3.4.7. The driven V-belt shall be rated at 150% of the operating motor power input. Provide adjustable sheaves on the motor, capable of 20% adjustment in fan speed, with the design fan capacity settling at approximately the midpoint of the adjustment. Belt speed shall not exceed 25m/s.

A12.3.4.8. Type of V-belt shall be in accordance with the "Standards for Light-duty or Fractional-Horsepower V-Belts" of Rubber Manufacturers Association.

A12.3.4.9. Belt guards shall be of heavy gauge steel framing with expended mesh screen.

A12.3.4.10. All belt guards shall have access openings at the shaft ends to enable tachometer readings to be taken.

A12.3.4.11. Vibration isolators shall be provided in accordance with "Acoustic Treatment and Vibration Control" sectionof this M&W Specification.

A12.3.4.12. The shafts shall be carried in ring lubricated self-aligning sleeve bearings for shafts of 150mm diameter and larger. Each bearing shall have large oil storage capacity to ensure efficient lubrication. On shafts of sizes smaller than 150mm diameter, grease lubricated self-aligning ball bearings resiliently mounted to reduce noise transmission shall be used.

A12.3.4.13. The shafts shall be extended beyond the drive-side bearing and keyed for overhung pulley in all cases.

A12.3.4.14. For centrifugal fans used in air handling units (AHUs) and primary air handling units (PAUs), one coat of corrosion-proof coating shall be applied to all non-working surfaces of shafts at the factory.

A12.3.4.15. The bearing life of the fan motor assembly shall be of 40,000 hours (L-10 life).

A12.3.5. Smoke Extraction and Pressurization Fans

A12.3.5.1. In addition to the aforesaid requirements stipulated in this M&W Specification, all fans used for smoke extraction and pressurization shall comply with additional requirements specified in this Clause.

A12.3.5.2. Smoke extraction fans shall be rated to deliver the designed flow rate and pressure for continuous operation in an air stream temperature of 250° C for not less than 2 hour.

A12.3.5.3. Not used

A12.3.5.4. All finishes shall be factory-applied and certified by the respective manufacturer that the finishing materials are capable of withstanding exposure continuously to an air stream temperature of 250 °C for not less than 2 hours without producing smoke or any toxic fumes.

A12.3.5.5. Motor winding of smoke extraction fans shall be insulated to permit motor operation at design conditions for continuous operation in an air stream temperature of 250 °C for not less than 2 hour. The smoke extraction fans shall be performance tested at factory for the performance and operating condition before delivery. Type test certificates shall be submitted to the Engineer for Approval.

A12.3.5.6. Not used

A12.3.6. Installation

A12.3.6.1. All belts, pulleys, chains, gears, couplings, projecting set screws, keys and other rotating parts shall be adequately guarded so that any person can safely come in close proximity thereto.

A12.3.6.2. Fit fans and appurtenances to the space provided and make readily serviceable.

A12.3.6.3. Provide support beams, support legs, platforms, hangers and anchor bolts required for the proper installation of equipment as shown on the Drawings or as recommended by the manufacturer and Approved by the Engineer.

A12.3.6.4. Provide permanently attached lifting eyes of sufficient number for on Site installation and future dismounting of fan units.

A12.3.6.5. Provide factory inlet bells and other accessories for fan units as shown on the Drawings or otherwise required for a complete and efficient installation.

A12.3.6.6. Where corrosion can occur, appropriate corrosion resistance materials and installation methods shall be used including isolation of dissimilar metals against galvanic interaction.

A12.3.6.7. Thoroughly clean the entire system before installing filters or operating the fans.

A12.3.6.8. For systems containing filters, install filters and permanently seal the filter frame air-tight before operating the fans. Replace all dirty filters and filter media before handing over the system to the Employer.

A12.3.6.9. Means of protection against overcurrent in the motor shall be incorporated in the control equipment when the motor rating exceeds 0.37 kW.

A12.3.6.10. A hole in the blanking off plate shall be provided for the cables leading to the fans. The hole shall be sealed around the cables with material suitable for sealing the hole effectively and continuously exposed to an air stream temperature of 250 °C for not less than 2 hours rating if the fans are used for smoke extraction.

DATA SHEET FOR AXIAL FLOW FANS FOR ECS	
Type	Vane/Tube Axial (Long Casing Type)
Reference Code / Standard	AMCA 210, ISO5801, BS848

Capacity	As per BOQ
Flow	Unidirectional
Noise	85 dBA at 1 meter
Total Pressure	As per BOQ
FAN	
Blade	Aerofoil Construction, Dynamically Balanced
Material	Aluminum alloy
Bearings	Totally sealed type Ball Bearing
Hub	Cast Aluminium Alloy
Casing	Rolled Steel Sheet, Heavy Gauge
Shaft	Solid Steel
Mounting	Shaft Key And Positive Locking Device
Drive Arrangement	Direct Drive
Motor	
Type	TEFC, IE-2, Induction Motor, Continuous Duty
Design	As Per IEC 60034
Power Supply	Three Phase, 415 V, 50 Hz, AC Power Supply IP 55 Protected
Mounting Arrangement	Suitable Bracket For Ceiling Suspension
Lifting Arrangement	Lifting Eye At Suitable Location And Number or as per manufacturer standard.
Paint	Synthetic Paint (Not required in case of 275 GSM or above, as per standard)

1. Lifting eyes / Flanges shall be provided for the lifting of fans.
2. Should be provided for spring isolators & to install fans as per manufacturer standard.
3. Flanges on the fans have sufficient strength to lift the fans.
4. Fans shall be provided with Flexible connections(Fire Rated in case of Fire Rated) with spring washers on both the side.

Section A13: ECS equipment control

TABLE OF CONTENT

A13.1. General

A13.1.1. This Section specifies the manufacture and installation of the ECS control equipment.

A13.2. Quality control

A13.2.1. Reference Codes and Standards

BS 4504 : Circular Flanges for Pipes, Valves and Fittings
BS EN ISO 6817 : Measurement of Conductive Liquid Flow in Closed Conduits – Method Using Electromagnetic Flowmeters
BS EN 60529 : Degrees of Protection Provided by Enclosures
Codes and regulations of the jurisdictional authorities.

A13.2.2. Furnish control hardwares which are products of a reputable control manufacturer who has made control equipment hardwares for a period of at least 10 years.

A13.3. Technical and Installation Requipments

A13.3.1. Control Valves

A13.3.1.1. All control valves shall have modulating actuators except that valves for FCU shall be provided with on/off valve actuators and shall be installed as indicated on the Drawings.

A13.3.1.2. All valves shall be sized by the Approved control equipment manufacturer to assure fully modulating operation as generally specified in this section of the M&W Specification. Valves indicated as full line size shall have properly sized internals. If valves smaller than line size are specified, reduction pieces for installation in line size indicated shall be provided. Manual override facilities as indicated on the Drawings shall be provided.

A13.3.1.3. Unless otherwise specified, control valves shall be normally closed, single-seated, cage-guided, brass/stainless steel trim, flanged 1500kPa cast-iron body with pilot positions. Valves shall be heavy duty with equal percentage, V-port plug. Pressure ratings shall be specified in the relevant clauses of this M&W Specification.

A13.3.1.4. Provide valve opening point at each actuator to indicate the valve opening and position.

A13.3.1.5. Fan Coil Control Valves

– Fan coil control valve operators shall be electric-thermal type operating on line voltage of 240V AC.
– Fan coil control valve bodies shall be 2-way, normally closed. Bodies shall be complete with union for connection.
– Fan coil control valve operators shall be of absolutely silent operation.
– Pressure drop across fan coil control valve shall be about 1 m. Valve working pressure shall not be less than 10 bar with 3 bar close off pressure.
– Fan coil control valves shall be equipped with automatic reset to automatic control mode after fully opened.

A13.3.2. Differential Pressure Control Valves

A13.3.2.1. Provide differential pressure control valves across the chilled water supply and return lines as indicated on the Drawings.

A13.3.2.2. Control valves shall comply with ANSI 300 with equal percentage V-port plug, normally close, electrically operated, single seated, cage guided, brass/stainless steel trim, bronze or cast-iron body. Pressure rating shall be as specified in Section 13 "Piping Ancillaries" of this M&W Specification.

A13.3.2.3. Valve shall be actuated by differential pressure controller, control function wide band proportional, integral and differential (PID) type with set point adjustment, display pointer, process variable display pointer, and a red pointer for high limit setting.

A13.3.2.4. Size the valve such that when fully open, 100 % of the rated flow of a circulating pump shall flow through the valve at the designed chilled water mains differential pressure.

A13.3.2.5. Provide a single seat valve across the differential bypass valve for manual bypass in case the two-way differential bypass valve malfunctions.

A13.3.3. Temperature Sensors/Transducers

A13.3.3.1. Duct mounted or immersion temperature sensors as indicated on the Drawings shall be suitable for use with the maximum system temperature and the maximum system pressure and described in other Sections of this M&W Specification. The sensor range shall be selected to give, where possible, the set point at the centre of the range. Sensors shall be of corrosion resistant construction, suitable for mounting on a vibrating surface.

A13.3.3.2. Immersion sensors shall be installed in stainless steel or copper wells packed with a heat transfer compound. The mouth of the well shall always be installed sufficiently above the external surface of pipework to retain the compound.

A13.3.3.3. Sensors shall be of tamper-proof construction, calibrated at the control manufacturer’s factory.

A13.3.3.4. Provide remote sensing element type for thermometers and pressure gauges where the location of sockets exceeds 2.0 m from floor level.

A13.3.4. Motorized Valve Operators – Refer Section A10

A13.3.5. Motorized Damper Operators

A13.3.5.1. Motorized damper actuator shall be of the piston or rotary type with a 550 to 700 kPa working pressure and shall be capable of actuating the dampers against a differential pressure of 2000 Pa across the dampers. Motorized damper actuators for smoke extraction, and staircase pressurization systems shall be fully operational after exposure to ambient air stream temperatures of 250°C for a continuous period of not less than one hour for smoke and fire dampers.

A13.3.5.2. Motorized damper actuators shall be provided with spring-return devices capable of driving the dampers to their de-energized positions within a period of 10 to 20 seconds after the motorized damper actuators are de-energized.

A13.3.5.3. Motorized damper actuators shall be mounted outside of the duct with support plates that are completely outside of the insulation or covering. Support plates shall be installed in a manner that will prevent condensation on the motorized damper actuator or on supports.

A13.3.5.4. Motorized damper actuator mountings shall be supported so that the actuator does not deflect from its normal path when operating under load.

A13.3.6. Differential Pressure Transmitters

A13.3.6.1. The transmitter shall work in conjunction with the flow measuring element and shall have adjustable range which is factory calibrated and secured and will match with the flow measuring element together with field adjustment of damping up to 30 second time constant. It shall have an indicator to monitor the process differential pressure, and 4 to 20mA DC output for central monitoring. The device shall be rated at the working pressure of water pipe and have overload protection in either direction.

Accuracy shall be better than ±0.5% of full scale with negligible dead band. Housing shall be weather-proof with teflon gasket and stainless-steel cover. Process connection shall be via stainless steel capillary complete with isolation valves and bypass valve.

A13.3.7. Limit Switches

A13.3.7.1. Limit switches for monitoring open and closed positions of motor operated dampers shall be designed to withstand the environmental condition of the ECS operation. All limit switches monitoring motor operated damper installations for smoke extraction and staircase pressurization systems shall be suitable for continuous operation in an air stream temperature of 250°C for not less than one hour. Each module of a multi-module damper shall be equipped with two status indicating limit switches. Each limit switch shall have two contacts, one normally open and one normally closed for status and alarm monitoring.

A13.3.7.2. Construction shall be suitable for outdoor installation with a centre neutral and two-point detection mechanism. Sensing arm shall be adjustable and lockable into desirable lengths to fit each specific installation. Standard mounting bracket shall be provided to facilitate adjustments on Site and shall be complete with cable terminal board and conduit fixings. Contact rating shall be 10 A minimum at 240 V AC with overall life of over one million operations at one ampere resistive load at 240 V AC.

A13.3.8. Automatic Flow Control Valves

A13.3.8.1. Provide automatic pressure compensating flow control valves of sizes as recommended by manufacturer to water system where indicated on the Drawings. Provide transformation pieces for valves larger than line size.

A13.3.8.2. Valves shall be factory set and shall automatically limit the rate of flow to the required capacity within 5 % accuracy over an operating pressure differential of at least 14 times the minimum required for control.

A13.3.8.3. The control mechanism of the valve shall consist of a self-contained open-chamber cartridge assembly with unobstructed flow. Internal working parts shall be Type 300 passivated stainless steel. Plated materials will not be accepted.

A13.3.8.4. The Type 300 passivated stainless steel cartidge assembly shall consist of a spring-loaded cup. The cup shall be guided at two points and shall utilise the full available differential pressure across the valve to actuate the cup and thereby reduce friction and hysterisis and eliminate binding. It shall have a thin orifice plate for self cleaning of the variable inlet ports over the full control range.

A13.3.8.5. Valves shall be available in four differential pressure ranges with minimum range requiring pressure of less than 10kPa to control the flow. Cast iron valve bodies shall be provided with inlet and outlet tappings suitable for connection of instruments for verification of flow rates. Valve bodies shall be rated for not less than 150% of system design working pressure.

A13.3.8.6. Submit certified performance data for the flow control valve based on independent laboratory tests for Approval.

A13.3.8.7. Each automatic flow control valve shall be provided with a valve kit consisting of 6.35mm by 50mm minimum size nipples, quick-disconnect valves (to be located outside of insulation), and fittings suitable for use with the measuring instruments specified.

A13.3.8.8. Provide a metal identification tag with chain for each installed valve. The tag to be marked with model number and rated flow rate in litres/second and GPM.

A13.3.8.9. Provide flow measuring instrument to verify flow rates. Correct flow shall be verified by establishing that the operating pressure differential across the valve tappings is within the range indicated on the submittal data sheet for that model number. The pressure measuring apparatus shall be portable.

A13.3.9. Electromagnetic Flowmeters

A13.3.9.1. The electromagnetic flowmeter shall operate on the principle of magnetic induction. The flowmeter shall comprise an in-line flow detector head and a separately mounted flow converter for producing a current and pulse output directly proportional to the flow rate of the liquid measured.

A13.3.9.2. The design and operation of the flowmeter shall comply with BS EN ISO 6817 with flange connection to BS 4504 PN 16.

A13.3.9.3. Test reports or certificates issued by the manufacturer to certify the measuring accuracy of the electromagnetic flowmeter shall be submitted for Approval.

A13.3.9.4. Materials of components of the flowmeter (including lining, measuring electrode) shall be suitable for use with the measured fluid.

A13.3.9.5. Design and measurement requirements:

– General
  (1) Overall accuracy : Better than ±0.5 % actual flow from 10 % to 100 % of flow range

  (2) Total power consumption : Less than 30 W.
  (3) Long term stability : Better than ±1 % of calibrated span per 12 months.
– Flow Detector Head
  (1) Field excitationer : Stabilized AC or bipolar pulses from flow converter.
– Flow Converter
  (1) Input signal : Induced e.m.f. from flow detector head.
– Output Signals
  (1) Current : 4-20 mA DC to drive 600 ohm maximum.
  (2) Pulse : 24 V/200 mA DC pulses with an adjustable maximum pulse rate of 5 pulses/ second suitable for driving a pair of electromechanical counters each with coil resistance of 180 ohms.
  (3) Low flow signal cut off : Automatic output signal cut off at less than 1 % of full scale flow range with resumption of normal measurement when flow is above 2 %.
  (4) Signal average time : Field adjustable between 0 to 5 seconds.
  (5) Linearity error : Better than ±0.5 % of span.
  (6) Repeatability : Better than ±0.1 % of span.

  (7) Supply voltage effects : Less than ±0.1 % of calibrated span per +/- 10 % change in supply voltage.
  (8) Frequency effects : Less than ±0.1 % of calibrated span per +/- 20 % change in supply frequency
  (9) Temperature effects : Less than ±0.05 % of calibrated span per °C.
  (10) Power supply : 240 V AC/50 Hz

A13.3.9.6. Flow Detector Heads

– The flow detector head shall be flanged at both ends to BS 4504 PN 16 suitable for installing in the pipeline between a fixed flanged at the upstream end and a straight pipe spigot cut to fit the installation at the downstream end by means of a slip-on coupling.
– The flow detector head shall be constructed from non-magnetic material lined with (PTFE) Telfon and pressure rating to PN16. The

field excitation coil assembly shall be epoxy resin encapsulated. The complete housing, including cable termination, shall have a certified degree of protection to BS EN 60529 IP54 for continuous 5m deep water submersion. External cable connections for field excitation and signal transmission shall be made via a sealable die-cast termination box or IP54 water-tight plugs and sockets.

- Suitable earthing arrangement shall be provided with the flowmeter. Resilient gaskets shall be provided for fitting between the flanges of the detector head and the pipeline. The gasket material shall be chemically resistant to the liquid being measured.
- The sensing electrodes shall be fabricated from stainless steel.
- The design and construction of the electrode assembly shall prevent any ingress of water into the detector coil housing. A liquid sensing electrode or equivalent device shall be fitted to the detector head to provide an automatic zero flow signal output when the metering tube is only partially filled with water.

A13.3.9.7. Flow Converters

- The electronics package shall be withdrawable to allow easy access to the circuit board for testing or fault diagnosis under operating conditions.
- The converter shall provide an automatic zero flow setting function to ensure that the flowmeter can be set up with stable zero point for measurement.
- The enclosure of the flow converter shall be to BS EN 60529 IP 65.
- 18.3.13.8 Accessories
- The Contractor shall provide the following accessories with each flowmeter:

  (1) A flanged end spigot, of the same size and pressure rating as the flowmeter, for connection at the
  downstream side of flowmeter and cut to fit the connection to the pipeline by means of a slip-on coupling;

  (2) One set of flange gaskets and bolts and nuts for each end of the flowmeter;

  (3) Screened cables for field excitation supply and flow signal transmission between the detector head and flow converter;

  (4) An electrode cleaning unit suitable for the fluid being measured; and

  (5) A portable electromagnetic flowmeter calibrator for checking/calibrating the flow converter.

A13.3.9.8. Testing

The following tests shall be carried out on certified testing apparatus at the manufacturer's works or other Approved testing facility.

(1) Pressure test to 150 % of the required working pressure;

(2) Flow calibration for the complete flow detector head and flow converter to verify the accuracy over the full flow range. The flow measurement shall be carried out using actual water flow rate through the flowmeter over the entire measuring range; and

(3) Degree of protection of the flow detector head to IP 54.

A13.3.9.9. Testing

- The following tests shall be carried out on certified testing apparatus at the manufacturer's works or other Approved testing facility.

  (1) Pressure test to 150 % of the required working pressure;

(2) Flow calibration for the complete flow detector head and flow converter to verify the accuracy over the full flow range. The flow measurement shall be carried out using actual water flow rate through the flowmeter over the entire measuring range; and
(3) Degree of protection of the flow detector head to IP 54.

A13.3.10. Static Pressure Sensors

A13.3.10.1. The sensor shall have a range of 0 to 1500 Pa, operate over a 500 Pa range, using a slack diaphragm sensing element, with force balance pneumatic feedback. The sensor shall have an accuracy of ±1%.

A13.3.10.2. Airflow Sensors

A13.3.10.3. The sensor shall be suitable for operation within the design velocity and temperature range and without any substantial change in the accuracy in its own operating conditions.

A13.3.10.4. Provide air straighteners and equal area transverse pressure sensors mounted in a complete galvanized iron casing.

A13.3.11. Water Flow Switches

A13.3.11.1. Flow switch shall be provided as shown on the Drawings.

A13.3.11.2. Switch cover and base plate shall be constructed of cast aluminium or hot-dipped galvanized cast steel and the paddle shall be of stainless steel. A rubber gasket shall be provided between the base plate and the cover.

A13.3.11.3. The paddle shall be able to be trimmed to size on Site and the unit shall be suitable for 240 V, single phase, 50 Hz operation.

A13.3.11.4. The assembly shall be properly rated and be suitable for the working pressure.

A13.3.11.5. The unit shall be installed in accordance with the recommendation of the manufacturer.

A13.3.12. Humidity Sensors

A13.3.12.1. Humidity sensors shall be of capacitance type and shall provide a voltage output between 0 to 10 V DC or 4 to 20mA.

A13.3.12.2. Sensors shall have a range of 20 to 90 % relative humidity.

A13.3.12.3. Room sensors shall be combined humidity/temperature sensors and shall have a connection plate to permit removal of the sensor during decoration of the room.

A13.3.12.4. Duct sensors shall have an insertion length of minimum 200mm and shall have a separate mounting flange with snap on connection to permit sensor removal.

A13.3.13. Level Controllers

A13.3.13.1. The unit shall consist of probe fitting complete with stainless steel probe rods (electrodes) and a controller

A13.3.13.2. The controller shall be operated in a bridged circuit principle with a built-in arrester circuit to protect against surge from power source and lightning surge from electrode side.

A13.3.13.3. The electrodes shall be capable of withstanding the corrosiveness of chemicals.

A13.3.13.4. Separators made of porcelain shall be provided to prevent short-circuit between electrodes.

A13.3.14. Water Level Controllers

A13.3.14.1. Water level controllers shall be fitted in water tanks for monitoring the water levels in the tank and to give the appropriate control/warning signals for the system. The water level controller shall be provided with built-in micro switches. The micro switches shall be protected with smooth polypropylene. No toxic material shall be used.

A13.3.14.2. The water level controllers shall be of submersible maintenance-free type.

A13.3.15. Modulating Damper Actuators

A13.3.15.1. Modulating damper actuators shall be spring return and electronic direct-coupled types, which require no crank arm and linkage.

A13.3.15.2. Modulating damper actuators shall be suitable for operation between 2 to 10 V DC. A 2 to 10 V DC feedback signal shall be provided for position indication.

A13.3.15.3. Modulating damper actuators shall provide clockwise or anti-clockwise fail safe operation as required by the Engineer.

A13.3.15.4. Modulating damper actuators shall use brushless DC motor and shall be protected from overload at all angles of rotation.

A13.3.15.5. Modulating damper actuators shall have a manual positioning mechanism and readily accessible.

A13.3.16. Installation

A13.3.16.1. Fit equipment and appurtenances to the space provided and make readily serviceable.

A13.3.16.2. Install the entire automatic control system, including control equipment and wiring under the supervision of the automatic control equipment manufacturer.

A13.3.16.3. Mount damper operators outside of the duct with support plates that are completely outside the insulation or covering. Install support plates in a manner that will prevent condensation on damper operator or on supports.

A13.3.16.4. Support valves and damper operator motor mountings so that the operator does not deflect from its normal path when operating under load.

A13.3.16.5. Locate sensing elements and duct sensors where they will respond to representative temperature within the duct or casing.

A13.3.16.6. Install duct sensors and remote transmitters outside of ducts and casings.

A13.3.16.7. Where ducts or casing are insulated, mount sensors flush with outside insulation so that moisture will not condense on sensors or on supports.

A13.3.16.8. Install duct sensor capillary tubes and wires to pierce the thermal insulation at the least practicable number of points

A13.3.16.9. Seal insulation properly where wiring passes through.

A13.3.16.10. Protect control wires by conduit or use flexible armoured cables. Coil control wires and fasten excess lengths to provide a tidy installation.

A13.3.16.11. The buttons side of control panel shall be mounted at 1200 mm above the finished floor level.

A13.3.16.12. Provide 100 mm clearance between rear of panel and wall by a bracket mounting.

A13.3.16.13. Mount controls, instrument gauges, thermostats and relays flush on the front of the panel.

A13.3.16.14. Mount framed schematic control diagram adjacent to each control panel or cabinet.

A13.3.17. Pressure Independent Control valve (AHU and FCU) – Refer Section A10

A13.3.18. <u>CARBON DI OXIDE & Air quality monitor SENSORS</u>

CO2 & air quality sensors shall be installed to monitor air quality in the public area during operational hours. CO2 & air quality sensors shall be connected with FAF fans in the ECS plant room through in built controller (VSD) which syncronise the freash air flow as per the requirement guided by CO2 & air quality level in the punlic area.

- CO_2 & air quality monitor cum sensor shall be provided for the occupied areas to monitor the CO_2 & air quality level.
- Lowest detection of the monitor shall be 0 to 2000 PPM with a resolution of less than 30 PPM.
- The sensing element for CO_2 & air quality sensor shall be dual beam infrared absorption type.
- The sensor shall have a relay output with programmable selection to control CO_2 & air quality .
- The communication interface shall be RS port.
- Visual digital display shall be provided which shall read CO_2 & air quality level in PPM.
- The sensor, monitor and all components shall be mounted in one neat and compact case, suitable for wall mounting. The indication light shall be mounted on the cover of the case, if surface mounted. All components shall be factory mounted.
- The monitor shall provide 4 to 20 mA or 0 to 10 volts DC output signal.
- The monitor shall be capable of interfacing with BMS.

Section A14: Acoustic treatment and vibration control

TABLE OF CONTENT

A14.1 General

A14.1.1 It is the intention of this Specification to direct the Contractor to provide sufficient noise and vibration control measures on his plant/equipment, the interconnected piping, ductwork and conduit so that when his systems are put into operation, the resulting noise and vibration levels at locations within the building and at adjacent locations shall not exceed the acceptable limits.

A14.1.2 Unless otherwise specified, the total noise level, whether it be airborne, structure-borne or duct-borne, shall not exceed the following limits when all the plant/equipment installed by the Contractor are put into operation:

At station concourse, platform and ancillary areas 55dBA

At the vertical surface, when measured at the nearest potential property line of a residence, commercial building or industrial building:

Urban, residential	50dBA
Urban, mixed	55dBA
Urban, non-residential	65dBA
Industrial	65dBA

A14.1.3 The noise level from the ventilation system shall not exceed 80dBA in the tunnel when used for applying ventilation under congested traffic conditions or smoke control in an emergency.

A14.2 Quality control

A14.2.1 Reference standards

ASTM C423: Sound Absorption and Sound Absorption Coefficients by the Reverberation Room Method
ASTM E90: Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions and Elements
ASTM E413: Rating Sound Insulation
ASTM E477: Test Method for Measuring Acoustical and Airflow Performance of Duct Liner Materials and Prefabricated Silencers
BS 476: Fire Tests on Building Materials and Structures
BS 2750: Measurement of Sound Insulation in Buildings and of Building Elements
BS 4718: Methods of Test for Silencers for Air Distribution Systems
BS 5588: Part 9: Fire Precautions in the Design and Construction of Buildings Part 9: Code of Practice for Ventilation and Air Conditioning Ductwork.
BS 8313: Code of Practice for Accommodation of Building Services in Ducts
BS EN 20354: Acoustics–Measurement of Sound Absorption in a Reverberation Room
IEC 60651: Sound Level Meters
NFPA 90A: Installation of Air-Conditioning and Ventilating Systems
ASHRAE Handbook

A14.3 Technical and installation requirements

A14.3.1 **Equipment Bases**

A14.3.1.1 Floor mounted equipment shall be installed on minimum 100mm high concrete housekeeping pads provided by the Building Contractor covering the whole floor area requirements of the equipment bases plus a minimum of 150mm further on each side. Vibration isolators are then mounted on this concrete pad.

A14.3.1.2 Unless otherwise directed in the Particular Specification, plant/equipment to be isolated shall either be supported by structural steel bases or concrete inertia bases.

A14.3.1.3 Welded Structural Steel Bases : Bases shall be constructed of adequate T or channel steel members reinforced as required to prevent the bases flexing at start-up and misalignment of drive and driven units.

A14.3.1.4 All perimeter members shall be steel sections with a minimum depth equal of 1/10th of the longest dimension of the base but need not exceed 350mm provided that the deflection and misalignment are kept within acceptable limits as determined by the isolated equipment manufacturer.

A14.3.1.5 Height saving brackets shall be employed in all mounting locations to provide a base clearance of 50mm.

A14.3.1.6 Detailed design calculations of the base and its anti-vibration isolator arrangements plus shop Drawings for each base shall be provided for approval before manufacture.

A14.3.2 **Concrete Inertia Bases**

A14.3.2.1 Concrete inertia bases shall be formed within a structural steel beam or channel frame reinforced as required preventing flexing, misalignment of the drive and driven units or transferral of stresses into equipment. The base shall be complete with height saving brackets, concrete reinforcement and equipment bolting down provisions.

A14.3.2.2 In general the thickness of concrete inertia bases shall be a minimum of 1/12th of the longest dimension of the base but never less than 150mm. The base depth needs not exceed 300mm unless specifically required.

A14.3.2.3 As anindication of the standards required, minimum thickness of the inertia base shall generally comply to the following table or be 1/12th of the longest dimension of the base, whichever is the larger:

Motor Size (kW)	Minimum Thickness
3.7 – 11	150mm
15 – 37	200mm
45 – 55	250mm
75 – 185	300mm

A14.3.2.4 Base forms shall include minimum concrete reinforcement consisting of 13mm bars or angles welded in place on 150mm centres running both ways in a layer 40mm above the bottom, or additional steel as is required by the structural conditions.

A14.3.2.5 Unless otherwise specified, concrete inertia bases shall weigh from 2 to 3 times the combined weight of the equipment/plant to be installed thereon.

A14.3.2.6 Base forms shall be furnished with drilled steel members and with anchor-bolt sleeves welded below the holes where the anchor bolts fall in concrete locations.

A14.3.2.7 Height saving brackets shall be provided in all mounting locations to maintain a base clearance of 50mm.

A14.3.2.8 Detailed design calculations of the base and its anti-vibration arrangement plus shop Definative Definitive Design Drawings for each base shall be provided for approval of the Contractor before manufacture.

A14.3.3 **Horizontal Pipe Isolation**

A14.3.3.1 All pipework in Auxiliary Building Chiller Plantroom and Cooling Tower Plantroom shall be suspended from vibration isolation hangers.

A14.3.3.2 All chilled water pipework suspended under station platforms (or in platform ceilings) shall be suspended from vibration isolation hangers.

A14.3.3.3 All rotating or reciprocating equipment shall be mounted on vibration isolation mountings or suspended from vibration isolation hangers.

A14.3.3.4 The Contractor shall be responsible for ensuring that there is no rigid connection in whatever form between the isolated equipment and the building structure, which will otherwise short-circuit the vibration isolation system and degrade its performance. This includes the necessary co-ordination with other trades by the Contractor.

A14.3.3.5 All isolators shall operate in the linear portion of their load versus deflection curve. Load versus deflection curves shall be furnished by the manufacturer, and must be linear over a deflection range of not less than 50% above the design deflection.

A14.3.3.6 All vibration isolators shall have their known undeflected heights or calibration markings so that, after adjustment when carrying their loads, the deflection under load can be verified, thus determining that the load is within the proper range of the device and that correct degree of vibration isolation is being achieved according to the design.

A14.3.3.7 The static deflection of the isolator at each support point shall not differ from the design objective for the equipment as a whole by more than ±10%.

A14.3.3.8 The ratio of lateral to vertical stiffness for springs shall be not less than 0.9 nor greater than 1.5.

A14.3.3.9 All neoprene mountings shall have hardness of 40 to 65 durometer, after minimum aging of 20 days or corresponding over-aging.

A14.3.3..10 In order to resist corrosion, all vibration isolation mountings and hangers shall be treated as follows:

- Springs to be neoprene coated or hot dip galvanised.
- Wearing hardware to be cadmium plated steel with stainless steel of an appropriate grade.
- All other metal parts to be hot dip galvanised.

A14.3.3..11 For a particular contract, all vibration isolators and associated equipment bases shall whenever possible be the product of a single manufacturer. Acceptable manufacturer's systems shall strictly comply with the design intent of this.

A14.3.4 **Selection Guide for Equipment Base and Vibration Isolator**

A14.3.4.1 Unless otherwise specified, the selection of type of equipment base and vibration isolator (mounting/hanger) for differing plant/equipment and on differing floor spans & levels may follow the requirements as indicated in the Selection Guide for Vibration Isolation. Table 48 Chapter 47 of the ASHRAE Application's Handbook 2007 or its latest edition, and the static deflection of the vibration isolator selected shall either provide a minimum isolation efficiency of 90% in ground floor areas and 95% in upper level areas or be not less than the corresponding values shown in Table 48. However, the Contractor is responsible for ensuring that the selected vibration isolation system is suitable for his specific plant/equipment and the specific building structure on which the plant/equipment is mounted.

A14.3.4.2 The Contractor shall provide more efficient isolation than those suggested in Table 48 if the adjacent occupied space is a noise critical area such as board room or executive office. Advice from vibration isolator manufacture shall be sought if necessary.

A14.3.5 **Method of Installation**

A14.3.5.1 The equipment structural steel or concrete inertia base shall be place in position and supported temporarily by blocks or shims. The machinery shall then be installed on the base and when that is complete, the isolators are to be installed without raising the machine and frame assembly.

A14.3.5.2 After the entire installation is complete and under full operational load, the isolators shall be adjusted such that the load is transferred from the blocks to the isolators. When all isolators are properly adjusted, the blocks or shims will become slightly free and can then be removed.

A14.3.5.3 The springs of vibration isolators shall in general have a loaded working height equal to 1.0 to 1.5 times the outside diameter of the spring and shall be compressed to approx. 50% of their unloaded height.

A14.3.5.4 Where any vibration isolation system permits equipment motion in all directions, provide where necessary additional resilient restraints to flexibly limit the lateral movement of the equipment to 6mm at start and stop.

A14.3.5.6 Prior to start-up, remove all foreign matter underneath the equipment base and verify that there is no short-circuiting of the vibration isolation system.

A14.3.5.7 Electrical circuit connections to isolated equipment shall be looped to allow free motion of isolated equipment.

A14.3.6 **Pipework Vibration Isolation**

A14.3.6.1 Unless otherwise indicated, all piping located in mechanical equipment rooms and having connections to vibrating equipment shall be isolated from the building structure by means of noise and vibration isolation hangers for a distance of at least 15m or 100 times the pipe diameter from the vibration equipment, whichever is the greater. This “floated” pipe run shall include, where situation permits, bends in two mutually perpendicular directions in order to give three degrees of freedom of movement, with approximately equal distance between successive elbows or bends.

A14.3.6.2 All horizontal and vertical pipework throughout the building that has connection to vibrating equipment shall also be isolated from the building structure by means of noise and vibration isolation guides and supports.

A14.3.6.3 All piping to be isolated shall freely pass through walls and floors without rigid connections. Penetration points shall be sleeved or otherwise formed to allow passage of piping, and a clearance of 10 to 15mm around the outside of the piping shall be maintained. This clearance space shall be lightly packed with glass fibre or rock wool and caulked airtight after installation of piping. Alternatively, factory fabricated split wall/floor seals may be used.

A14.3.6.4 The inlet and outlet connections of all vibrating equipment shall be fitted with either flexible connectors or flexible hoses as appropriate.

A14.3.6.5 Horizontal Pipe Isolation : Where horizontal pipe isolation is required, the first three pipe hangers in the main line near the mechanical equipment shall be of Pre-Compressed Spring Hangers and the hangers for the horizontal run in all other locations shall be of Spring Hangers or Spring and Double Deflection Neoprene Hangers, the latter being used for more sensitive situations where a higher degree of noise and vibration attenuation is required.

A14.3.6.5 Pre-Compressed Spring hangers shall have the same static deflection as that of the mountings under the connected equipment. Spring Hangers and Spring and Double Deflection Neoprene Hangers shall have a minimum deflection of 20mm.

A14.3.6.6 Pipe Riser Isolation : Where pipe riser isolation is required, the pipe risers to be isolated shall be suspended from Pre-Compressed Spring hanger or supported by Restrained Spring mountings and anchored with pipe anchors or guided by pipe guides. Steel spring deflections shall be a minimum of 20mm except in those expansion locations where additional deflection is required to limit deflection or load changes to plus or minus 25% of the initial stress.

A14.3.6.7 Flexible connectors shall be fitted to the inlet and outlet connections of all pumps, water chillers, water towers ad other centrifugal or reciprocating vibrating equipment.

A14.3.6.8 Flexible connectors shall be the full line size of the equipment connection and fitted as close to the source of vibration as is practical. Straight connectors shall, where practical, be installed in a position that is parallel to the equipment shaft, as equipment vibration tends to be most severe in a direction radial to the shaft.

A14.3.6.9 Flexible connectors shall consist of a single or twin-sphere body manufactured with reinforced rubber, the ends of which are raised and wire reinforced to form the cuffs for sealing purposes. The cuffs shall be backed by floating steel flanges.

A14.3.6.10 For use in water, the rubber type shall be EPDM. For other duties, a suitable rubber shall be selected in accordance with the manufacturer's recommendation.

A14.3.6.11 The rubber body shall be reinforced by multi-layered nylon tire cord fabric.

A14.3.6.12 Flexible connectors shall have a life in excess of 10 years under the design working conditions.

A14.3.6.13 Flexible connection shall be installed at all fancoils, AHU's, fans and from duct branch takeoffs to risers in platform area.

A14.3.6.14 The rubber membranes shall have an indelible identification system to clearly identify the model and hence suitability for the application and working conditions and shall have the date of manufacture moulded into the cover to ensure no units are used that have exceeded their recommended shelf life.

A14.3.6.15 Straight connectors shall be of twin-sphere construction whilst elbow connectors shall be of single-sphere construction.

A14.3.6.16 Straight connectors connected to resiliently supported equipment must be equipped with acoustic control cables to prevent excessive elongation of the connectors if the system operating pressure is in excess of the value recommended by the manufacturer for use without control cables.

A14.3.6.17 Acoustic control cable assembly shall consist of four large triangle anchor plates, two control cables with large swaged-on end fittings and 13mm thick acoustic washer bushings of sufficiently large load bearing area to isolate the end fittings, axially and laterally.

A14.3.6.18 Flexible Metallic Hose :For higher operating temperatures and pressures, vibration movement generated by pumps, chillers, water towers, air handling units and the like shall be accommodated by braided flexible metallic hoses. Allowable stress levels should be within BS 5500 1985 or equivalent standard.

A14.3.6.19 The corrugated seamless hose body shall be of annular and lose pitched type.

A14.3.6.20 For all ferrous applications, the hose body and the braid shall be manufactured from stainless steel material to BS 1449 part 2, Type 321S31 or equivalent. End terminations shall be carbon steel threaded made nipples for 50mm size and below and flange connections for 65mm and above.

A14.3.6.21 For copper or non-ferrous pipework systems, the hose body and the braid shall be manufactured in bronze throughout. End terminations shall be copper female ferules suitable for soldering.

A14.3.6.22 The lengths of the flexible metallic hoses shall be in accordance with manufacturer's recommendation.

A14.3.6.23 Since the braid is stretched taut by the pressure in the axial direction, hoses cannot accept axial motion. Therefore, the hoses shall be installed on the equipment side of the shut off valves and be installed parallel to the shaft for best performance so that the vibration movement is perpendicular to the axis of the hose. A pipe anchor capable of withstanding the deflection forces generated by the flexible hose shall be installed immediately after the hose in order to force the hose to flex transversely.

A14.3.6.24 Two hoses at right angles to each other shall be provided when major vibration motions are to be isolated exist in two planes.

A14.3.7 Ductwork Vibration Isolation

A14.3.7.1 Flexible connections shall be provided between the vibrating equipment and the ductwork and shall be made of approved materials such as lead vinyl or similar of minimum surface density of 5kg/m² and installed such that airflow is not obstructed. The material used must be in compliance with local statutory requirements for fire retardant period but this period shall not be less than 2 hours.

A14.3.7.2 Unless otherwise specified, all discharge duct runs for a distance of 15m from the connected vibrating equipment which has a discharge pressure of 1 kPa or above shall be isolated from the building structure by means of spring hangers. Spring deflections shall be a minimum of 20mm.

A14.3.7.3 Except in the case of ducts passing through compartment walls requiring a fire damper, all ductwork to be isolated shall freely pass through walls and floors without rigid connections. Penetration points shall be sleeved or otherwise formed to allow passage of ductwork, and a clearance of 20 to 32mm around the outside surface of the ducts shall be maintained. This clearance space shall be tightly packed with glass fibre and caulked airtight after installation of ductwork.

A14.3.7.4 In cases where a fire damper is required, ductwork to be isolated shall be fitted with a flexible joint on the side of the fire damper from where the vibration originates.

A14.3.8 Ductwork Acoustic Insulation

A14.3.8.1 Unless otherwise specified, the acoustic duct liner shall conform to the requirements of ASTM C1071 Type II. It shall be composed of long textile-type glass fibres firmly bonded together with a thermosetting resin into a rigid board of 50mm thickness and 48 kg/m^3 density. The air stream surface shall be overlaid with a fire-resistant black acrylic coating that adds strength to the product during fabrication, installation and system operation. The manufacturer's product identification shall appear on the air stream surface.

A14.3.8.2 Transverse joints of the duct linerboard shall be neatly butted and there shall be no gaps. Board shall be cut to assure tight, overlapped corner joints. Board shall be adhered to the sheet metal duct with 100% coverage of adhesive conforming to ASTM C-916, and all exposed edges and joints shall also be coated with adhesive. Board shall be additionally secured with mechanical fasteners that shall start within 75mm of the upstream transverse edges and 75mm from the longitudinal joints and be spaced at a maximum of 150mm centres around the perimeter of the duct and 100mm from corner joints. Elsewhere the fasteners shall be spaced at a maximum of 150mm centres in the direction across width of duct and 400mm centres in the direction along length of duct and not more than 75mm from longitudinal joints and 100mm from corner joints. Entering and leaving edges of the duct linerboards shall be provided with continuous sheet metal edge protectors.

A14.3.8.3 All components of the acoustic insulation including coverings and adhesive shall have a fire hazard classification with a flame spread rating of not over 25, and a smoke developed rating of not-over 50. Ratings shall be established by tests conducted in accordance with UL 723, ASTM E-84 or NFPA 255. The Contractor shall certify in writing, before any insulation is installed, that the products to be used meet the above criteria.

A14.3.8.4 The acoustic linings shall have the following minimum sound absorption coefficients when tested in accordance with ASTM C-423.

Octave Band Centre Freq. (Hz)	125	250	500	1k	2k	4k
Sound Absorption Coefficient	0.12	0.67	0.99	0.97	0.91	0.87

A14.3.8.5 Air duct internal linings shall not be installed within 1m of the fire damper.

A14.3.8.6 Where internally lined ductwork is used for smoke exhaust or pressurisation systems, the surface shall be additionally protected by a perforated sheet metal covering securely fitted as an internal duct to ensure the lining does not break free of the duct wall.

A14.3.9 Acoustic Duct lag

A14.3.9.1 Unless otherwise specified, the acoustic duct lag shall consist of 50mm thick glass fibre/lead sheet/glass fibre with a factory applied aluminium vapour-barrier jacket that shall also be used for thermal insulation of ductwork.

A14.3.9.1 The fibreglass shall have a density of 24kg/m^3 and thermal conductivity of 0.032W/m°C or lower. The lead sheet shall have a surface weight of 5kg/m^2.

A14.3.9.3 Duct lag shall have the following minimum sound transmission loss when tested in accordance with ASTM E-90.

Octave Band Centre Freq. (Hz)	125	250	500	1k	2k	4k
Sound Transmission Coefficient	15	17	19	24	30	33

A14.3.9.4 The Contractor shall submit installation details to the Contractor for approval prior to installation.

A14.3.10 Duct Silencers

A14.3.10.1 The outer casing of rectangular duct silencers shall be fabricated from not lighter than 0.8mm galvanised steel in accordance with the recommended practices in the ASHRAE Guide. Seams shall be lock-formed and mastic filled. Each silencer shall be provided with a flanged inlet and outlet. The internal baffles or splitters shall be not lighter than 0.5mm galvanised perforated steel having a nominal open area of 30%.

A14.3.10.2 All internal components shall be spot welded in place with welds on centres not exceeding 100mm. All spot welds shall be treated after welding with anti-corrosive epoxy resin or other approved coating.

A14.3.10.3 Manifolded silencers shall be installed with continuous metallic nosing crimped in place. Nosing pieces and tails shall be as per manufacturer's design. The filler material shall be of inorganic mineral or glass fibre of a density sufficient to obtain the specified acoustic performance and be packed under not less than 5% compression to eliminate voids due to vibration and settling. Material shall be inert, vermin and moisture proof.

A14.3.10.4 Combustion rating for the silencer acoustic in-fill shall not exceed the following when tested in accordance with ASTM E-84, NFPA Standard 255 or UL No. 723:

Flame Spread	25
Smoke Developed	15
Fuel Contributed	20

A14.3.10.5 The silencer shall be leak-proof at a differential air pressure of 2 kPa.

A14.3.10.6 Before ordering duct silencers the Contractor shall submit for the Contractor's approval the proposed manufacturer's certified test data for pressure drop and insertion loss ratings.

A14.3.11 Acouctic Enclosure

A14.3.11.1 Acoustic enclosures for equipment shall be fabricated from 18 G GI sheets, with 50 mm thick fibreglass, as specified for ductwork acoustic insulation, covered with 0.5 mm thick perforated aluminium sheet.

A14.3.12Acoustic Lining of Equipment Rooms:

The walls and ceiling of AHU room shall be provided with fix resin bonded glass wool 50mm thick of density 32 kg/m3 for acoustic lining as per following specifications:

Installation:

- Clean the surface
- Fix section (size 25 x 50 x 50 x 50 x 25mm) fabricated out of 24G GI frame with spacing not more than 600mm x 600mm center to center to be laid in horizontal and vertical formation.
- Fix resin bonded glass wool 50mm thick of density of 32 Kg./m3 in the GI frame and cover with tissue paper.
- Cover the insulation with 0.8mm perforated aluminium sheet with at least 20% perforation.
- Cover the joints in aluminium sheet with 25mm x 1mm aluminim beading secured with GI frame by means of steel screws.

Section A15: Low Voltage Electrical Panel

1. DETAILED DESCRIPTION OF THE EQUIPMENT AND ITS APPLICATION IN DMRC: LOW VOLATGE ELECTRICAL PANELS

1.1 Metro stations namely Rail corridor stations, Under-ground stations as well as on-grade stations and Depot are provided with Electrical Panels for receiving and distribution of power supply to various usages as defined in various clauses at voltage level of 415 V/50 Hz. The usages are generally lighting, air conditioning system, ECS system, PD area and all other type E&M work which come under stations coverage. Switch boards and panels as per following list are provided for power supply distribution at metro stations and in depots.

1.2 The bidders shall refer the BOQ and drawing for incoming feeders, outgoing-feeders, indications, metering and protection details along with quantity and type of each.

1.3 The panels are generally named as follows:

- Main Distribution Board (MDB)
- Sub-main Distribution Board (SMDB)
- Essential power panel (EPP)
- Emergency Power Panel (EMLP)
- Local Motor Control Panel (LMCP)
- Main Lighting Panel (MLP)
- Air conditioning Power panel (ACPP)
- Fire pump panel (FPP)
- Water pump panel (WPP)
- Passenger Amenities Panel (PAP)
- Light Distribution Boards (LDB)
- APFC Panel

1.4 The manufacturing , testing , installation and commissioning of complete 415 V, 3 phase, 4 wire and 50 Hz low voltage main switchboard is as defined in IEC/EN 61439-1, built up from compartments to house busbars , terminal blocks, internal and control wiring, instrumentation, relays, interlock and padlocking facility, emergency push buttons, equipment for BMS/ SCADA /RS 485/ Mod bus connectivity of communicable ACB/MCCB interface, indication lamps, control and auxiliary switches, contacts, control power supply, air circuit breaker, MCCB, MCB, CTs and PTs, APFCs and any other items considered necessary to deliver the functions of incoming and outgoing power supply as detailed in BOQ and drawing.

1.5 The equipments installed in each of the Electrical Panel are defined in the BOQ.

2. GOVERNING SPECIFICATIONS

Electrical Panels along with equipments shall conform to the latest standard or harmonize as per the respective standard as given below or specified along with the equipment in the specification.

In case of any conflict between specifications & the standards, the instructions/decision of the Engineer' or Employer's authorized representative shall be binding.

2.1 STANDARDS

Low voltage Electrical Panels shall satisfy the following requirements and shall also comply with standards in force when Electrical Panel units are manufactured, particularly which are in the following table (Unless otherwise stipulated in the specification, the latest version of the standards shall be applicable)

STANDARD	DESCRIPTION
ISO STANDARD	
ISO 9001	Quality systems- model for quality assurance in design/development, production, installation and servicing
IEC STANDARD	
IEC 60228	Conductors of insulated cables
IEC 60255	Measuring relays and protection equipment
IEC 60529	Degrees of protection provided by enclosures (IP Code)
IEC 60831	Shunt power capacitors of the self-healing type for a.c. systems having a rated voltage up to and including 1000 V
IEC 60871	Shunt capacitors for a.c. power systems having a rated voltage above 1000 V
IEC 60898	Electrical accessories – Circuit-breakers for over current protection for household and similar installations.
IEC 60947-6-1/EN 60947-6-1	Specification for low-voltage and control gear Multiple function equipment. Automatic transfer switching equipment.
IEC 60947-2/EN 60947-2	Specification for low-voltage switchgear and control gear circuit breakers.
IEC 60947-1	Specification for low-voltage switchgear and control gear. Contactors and motor-starters. Electromechanical contactors and motor-starters.
IEC 61008	Residual current operated circuit-breakers without integral over current protection for household and similar uses (RCCBs)
IEC 61439-3/EN 61439-3	Specification for low-voltage switchgear and control gear assemblies. Particular requirements for low-voltage switchgear and control gear assemblies intended to be installed in place.
IEC 61439	Specification for low-voltage switchgear and control gear assemblies
IEC 62262	Degrees of protection provided by enclosures for electrical equipment against mechanical impacts (IK code)
IEC 61641	Enclosed low-voltage switchgear and control gear assemblies - Guide for testing under conditions of arcing due to internal fault.
IEC 61869/BSEN 61869	Instrument transformers
IEC 61009	Specification current operated circuit-breakers

	without integral over current protection for household and similar uses (RCBOs)
IEC 62052-11, IEC 62053-21	Direct reading single/three phases meter (Digital Type) up to 600 V.
IS STANDARD	
IS 13779	ac Static Watt-hour Meters, Class 1 and 2
IS 13947-5-2	Low-Voltage Switchgear and Control gear, Part 5: Control Circuit Devices and Switching Elements, Section 2: Proximity Switches
IS 13947-5-1	Low-Voltage Switchgear and Control gear, Part 5: Control Circuit Devices and Switching Elements, Section 1: Electromechanical Control Circuit
IS 13947-4-1	Low-Voltage Switchgear and Control gear : Part 4 - Contractors and Motor-Starters
Is 13947-3	Low voltage switchgear and control gear, part 3: switches, disconnectors, switch-disconnectors and fuse combination units
IS 13947-2	Low-Voltage Switchgear and Control gear, Part 2: Circuit Breakers
IS 13947-1	Low-voltage switchgear and control gear, Part 1: General rules
IS 5553	Reactors – Specification
BS STANDARDS	
BS 381 C	Colour chart
BS 4800	Colour
BSEN 60742/BS 3535/BS 61558	Isolating Transformers
BS 1432	Specification for Copper for electrical purpose high conductivity copper rectangular conductor with drawn or rolled edges.
BS 951	Electrical earthing. Clamps for earthing and bonding. Specification
BS 7430	Code of practice for protective earthing of electrical installations
BS EN 13601	copper and copper alloys - copper rod, bar and wire for general electrical purposes
IEC/BS EN 60947-4-1	Specification for low-voltage switchgear and control gear. Contactors and motor-starters. Electromechanical contactors and motor-starters.
BS EN 10025	Hot rolled products of structural steels
BS EN 50525	Electric cables. Low voltage energy cables of rated voltages up to and including 450/750 V (U0/U)

2.2 Abbreviations

ACB- Air Circuit Breaker

APFC-Automatic power factor correction

ALTS-Automatic Load transfer Switch

ATS- Automatic transfer switch

DB- Distribution board

EMC- Electromagnetic compatibility

LEP- Local Electrical Panel

LMCP- Local motor control panel

LT- Low Tension

LVDB-low voltage distribution board

ELECTRICAL PANELS- Low Voltage main switch board

BMS- Building management System

MCB- Miniature circuit breaker

MCCB-moulded case circuit breaker

MFM- Multi function meter

MPCB-Motor protection circuit breaker

RCCB- Residual current circuit breaker

RTU- Remote terminal unit

SELECTRICAL PANELS- Sub Main Distribution Board

TB- Terminal block

VFC- Volt free contact

3. TECHNICAL AND INSTALLATION REQUIREMENT

3.1 GENERAL AND TECHNICAL REQUIREMENTS OF ELECTRICAL PANELS

3.1.1 The Electrical Panel shall be same as low- voltage switchgear and control-gear assemblies defined in IEC 61439-1 or EN 61439-1 built up from compartments housing circuit breakers, control gear, relays, bus bars, controls and other equipment as defined in BOQ. All Type tests are from acceptable, accredited and independent testing laboratory.

3.1.2 All panels should be factory built of proven design with OEMs as well as switchboard manufacturer approved as covered by clause 3.10 of IEC 61439-1.

3.1.3 The Electrical Panel shall pass the internal arc fault containment tests in accordance with IEC 61641 for fault current ratings as defined in BOQ for a minimum time of 0.3 sec.

3.1.4 The degree of Ingress Protection for Electrical Panels shall be IP 54 for underground and IP 42 for Elevated/Depot unless otherwise specified in BOQ, as defined in IEC 60529 which shall not deteorate with time.

3.1.5 The Electrical Panels and the associated equipment, including switchgear and control gear assemblies shall be certified for the category of duty specified as per Annex A of IS/IEC 60947-1.

3.1.6 The main circuit as defined in vide clause 3.1.3 of IEC 61439-1 shall have an insulation voltage of 1000 V AC or as specified in the BOQ.

3.1.7 The ambient temperature and ambient humidity for Electrical Panel shall be as per IEC 61439-1 (clause 7.1.1 and 7.1.2 of IEC 61439-1) and Switchgear shall be as per IEC 60947(Clause 6.1.1 and 6.1.3 of IEC 60947).

3.1.8 The secure service life of Electrical Panels shall be at least 30 years as defined in General Scope of Work. The design features to secure the service life of 30 years shall be submitted at the time of design approval.

3.1.9 The Electrical Panel shall have a rated short time withstand current of 70 kA, 65 kA, 50 kA and 35 kA for 1 second as per BOQ.

3.1.10 The Electrical Panels shall be a minimum of Form 4b Type 5 in accordance with BS EN 61439-2/IEC 61439-2 & Eiema's Guide To Forms Of Sepration.

3.1.11 **All materials like busbar supports etc used in the panels shall be Low Smoke Zero halogen and Thermosetting type.**

3.2 ELECTRICAL PANEL CONSTRUCTION

3.2.1 The panels shall be of the approved design to suit local conditions as prevailing at different metro stations.

3.2.2 The Electrical Panel (other than DB) shall be designed for indoor use in the form of free standing, floor mounting extendible, self contained, flush fronted cubicles and sectionalized as necessary to face easy transportation and erection, containing all the equipment indicated on the Drawing, BOQ and specified hereinafter.

3.2.3 The cubicle section shall be constructed of angle iron types frames or folded sheet steel or fully welded/bolted construction with all necessary removable covers. Removable lifting lugs shall be provided on the top of the cubicles. Cubicle sections shall be provided with bolts or devices for insuring that they are correctly aligned when being coupled together. The bus bar chamber shall be fitted with removable end cover plates secured by mild steel captive screws.

3.2.4 It shall be finished to provide a rigid shell type of enclosure in accordance with BS EN 10025.

3.2.5 The load bearing parts of the entire electrical panel assembly shall be 2 mm CRCA thick sheet whereas other partition parts shall be constructed of minimum 1.6 mm CRCA thick sheet steel.

3.2.6 The Electrical Panels shall be mounted on a robust base frame made up of steel channel with a minimum height of 100mm and the maximum height of Electrical Panel shall not exceed 2.40 meter including base frame. The base frame shall be able to withstand the static and dynamic loads of the Electrical Panels. The steel channels shall be painted with epoxy polyester paint. The main contractor shall ensure that the maximum height of the Electrical Panel at the site of installation shall not exceed 2.6 meter including foundation if any.

3.2.7 Electrical panel shall have provision for top/bottom in-coming and bottom/top out-going to suit site conditions of cable entries.

3.2.8 Non-magnetic gland plates of not less than 5 mm thick of suitable size shall be provided at the top and bottom of the LV main switchboards for the termination of incoming and outgoing power cables of size 120 sq. mm or more or bus ways and 3 mm thick for cables of size less than 120 sq. mm. Where armoured multi-core cables terminate inside the switchboard enclosure, glanding plates or glanding brackets shall be provided for securing the cables to the switchboard.

3.2.9 Glanding plates, glanding brackets and extension boxes shall be removable and shall be of adequate size for the particular cables to be terminated. The cables shall not put any stress on to the glanding plate and shall be secured adequately.

3.2.10 All relays and indicating instruments shall be at least 300 mm and not higher than 1.8 m from base frame. The clearance in front, back and side of all assemblies of switchgear and control gear shall be as per latest IE rule. .

3.2.11 Various units comprising a complete Electrical Panels shall be grouped in a multi-tier arrangement including a cabling and wiring chamber of ample dimensions to accommodate terminal blocks, cable boxes and gland plates.

3.2.12 The equipment shall be arranged within each compartment such that all normal maintenance can be carried out through hinged access doors or removable covers, and where possible from the front.

3.2.13 Adequate maintenance access shall be provided to equipment within the Electrical Panels. Demountable panels shall be provided at the back of the Electrical Panels that can be handled by a single person. Every demountable panel shall be provided with a pair of handles for easy removal and fixing.

3.2.14 Front access door shall be fixed with concealed hinges and interlocked with the switch mechanism. The door panel can be opened only if the switchgear is in the "OFF position" or the switchgear should switch off if the panel door is opened.

3.2.15 Ventilating louvers along with filter, where required, shallensuring compliance of IP 54. It shall be provided in such a way that it is easily accessible for cleaning or self cleaning filters shall be proved.

3.2.16 Anti-condensation heaters shall be provided at the rate of 60 W for each vertical of the Electrical Panels, incase the volume is greater than 1 cubic meter of one vertical then 2x60 W heater shall be provided. The heaters shall be of an enclosed tubular pattern, each separately fused/ MCBs and switch. Each heater shall be controlled by means of a step adjustable humidistat.

3.2.17 Adequate arrangements for air circulation shall be made within each compartment of the Electrical Panels, if required. The Contractor shall ensure that the internal temperature of the Electrical Panels will be well within the operating ranges as specified by IEC 61439-1 of all electric components including switchgear, control gear, bus bars, relays, wiring and timers inside the Electrical Panels.

3.2.18 All the incoming / outgoing terminations shall be extended via copper connections into a separate termination chamber adjacent to the switchboard. When busbars are used between switchboards, the internal busbars of the switchboard shall be of tinned copper bars sizes of copper shall be as per tested design. No linking of busbar or incoming/outgoing terminals with switchgears/functional units shall be permitted with cable except in case of MCCBs./MCBs below or equal to 100 Amps rating.

3.2.19 The switchgear assembly/sub-assemblies or panels shall be termite and rodent proof.

3.2.20 The switchboard shall have sufficient space to house all electrical equipment allowing spare Space capacity of 10% for the future expansion if specifically asked in BOQ

3.2.21 Spare feeder shall be provided as per BOQ. Any Panel which comprises an assembly of similar modules shall be constructed such that further similar modules can be added at either end.

3.2.22 All similar items of the Electrical Panels and their component shall be interchangeable. Spare parts shall be manufactured to originals and shall fit all similar items of the Electrical Panels. Where machining may be needed before fitting renewable parts, the machining fits and the associated tolerances shall be shown on the drawings accompanying the instruction manuals.

3.2.23 The Electrical Panel shall operate without excessive vibration and with a minimum of noise as per best of engineering practice and shall also operate without excessive temperature rise at the rated load conditions.

3.2.24 The style and finish of the workmanship shall be consistent throughout the Works. Unless otherwise specified, Engineer shall decide the final colours for all paintwork and other finishes to be applied to the Electrical Panels.

3.3 ELECTRICAL PANEL EARTHING AND SAFETY ARRANGEMENT

3.3.1 All non-current carrying metallic components shall be permanently connected to earth.

3.3.2 Material used for the earthing busbar shall be same as the main busbar.

3.3.3 The tin-plated copper earthing busbar inside the panel shall have cross-sectional area as per calculation given in Annex B.

3.3.4 A continuous earthing busbar shall be provided along the whole length of each Electrical Panels and shall be provided with terminals for connection to the metal housing of incoming busways, cable trunking and cladding or armouring of all incoming and outgoing cables and to the substation earth.

3.3.5 Switchboards shall be provided with two earthing terminals, one at each end, for the connection of external earth conductor for earthing. The earthing bars shall be fixed at rear interior bottom portion throughout the length of the switchboard, bonding all gland plates, and other component parts of the switchboard to a main earth point adjacent to the intake position in accordance with BS 951 and BS 7430.

3.3.6 All terminals, connections, relays and other components which may remain live when access doors are open shall be screened. It shall not be possible to obtain access to an adjacent cubicle when any door is opened.

3.3.7 Where several outgoing circuits occupy a common cabling chamber, all copper work, cable lugs, terminations and terminal blocks shall be fully segregated by compartmentation to enable work on any one circuit to be carried out with other circuits remain live.

3.3.8 Protection against shock in normal service shall be achieved by the provision of barriers or enclosures both vertical and horizontal and between adjacent units to ensure segregation and prevent accidental contact with live parts, or by complete insulation of all live parts Control cables shall be segregated from primary conductors.

3.3.9 The protective earthing configuration shall be TN-S unless otherwise specified.

4. EQUIPMENT INSTALLED INSIDE ELECTRICAL PANELS

Electrical panels consist of Low Voltage Switchgear, control wiring and all other parts which are defined below.

4.1 BUSBAR

4.1.1 Busbars shall be of rectangular section hard drawn high conductivity tinned copper bare type conform to BS 1432/13601 adequately rated for designed value and fault level of load as per BOQ and supported by non-tracking moulded insulators spaced at suitable intervals. The complete assembly shall be capable of withstanding the maximum mechanical stresses to which it may be subjected to under fault conditions.

4.1.2 Sizing of the busbar shall comply with IEC 60890 for temperature rise assessment by extrapolation and in case of copper busbar temperature rise as per Copper Development association latest formula, may also be used.

4.1.3 Bus bar rating shall be same through out the length of panel and shall be as per BOQ type tested design and recommendation of IEC 61439. The bus bar shall be designed for easy extension in future at either end.

4.1.4 Busbars and busbar connections shall be constructed in accordance with the requirements of IEC 61439-1. The short-time withstand current rating shall be as mentioned in BOQ for 1 second at 415 V.

4.1.5 Connection in Bus bars shall be made as approved and proven design of original manufacturer.

4.1.6 The maximum temperature of the bus bars and the bus connections shall be as per IEC 61439 standard.

4.1.7 The main busbars shall be so positioned and arranged that all busbar risers and droppers can be brought onto the main busbars without undue bending. Busbars shall be and supported with appropriate clearances in air to the requirement of providing full insulation.

4.1.8 Busbar chambers of similar rating shall be capable of coupled together using busbar coupling links, in accordance with the manufacturer’s recommendation. Coupling links shall be approved by the Engineer before use.

4.1.9 Interconnecting conductors between busbar chambers and switchgear shall be as per rating of switchgear and type tested design.

4.1.10 Switchgear shall be joined to busbar chambers by means of properly designed busbar chamber connection flanges or conduit couplers and male bushes. Connection flanges shall be manufactured from galvanized sheet steel or CRCA and finished grey.

4.1.11 Busbars shall be coloured for phase identification at location of bus inspection points with the approval of site Engineer. The material for phase identification shall be non-fading colour of proven design to be decided by the Engineer and use of adhesive label shall not be acceptable.

4.1.12 The front cover and end plates of busbar chamber shall be removable and normally held in position by non-ferrous metal screws.

4.2 POLARITY

4.2.1 The polarity of all apparatus shall be arranged as follows when viewed facing the front of the Electrical Panels:

a) For two pole apparatus, phase pole and neutral pole when reading from top to bottom or left to right; and

b) For three or four pole apparatus, red, yellow and blue phases and neutral when reading from top to bottom or left to right.

4.2.2 All cables shall be so connected within the Electrical Panels such that the correct sequences are preserved throughout.

4.3 CONTROL SUPPLY

4.3.1 Separate control bus of suitable rating made of copper shall be provided through out the panel length, and the control bus should be accessible from the front/back of the panel. Control voltage taping for different feeder shall be done with proper clamp.

4.3.2 The control circuit shall be separated from other auxiliary circuits, i.e. indicating circuit, heater and lighting circuits, with dedicated circuit protective devices.

4.3.3 240V control supply will be available from the station UPS with standby utility or as decided by engineer at site. DP MCB protection shall be provided at incoming.

4.3.4 240V Volt sensing relay with volt free contacts shall be provided for sensing the control supply for local and remote indication to BMS/SCADA.

4.4 INSTRUMENTATION

4.4.1 Electrical meters shall conform to IS 13779 / IEC 62052-11 62053-22 suitable for single phase /three phase supply system in all respects. Accuracy of meters shall be of class as specified in BOQ.

4.4.2 All meters shall be digital type and multifunction meters should be with RS 485 connectivity to suit BMS System wherever mentioned in BOQ. Suitable memory and software for logging the information along with real time metering information must be available. The meters must have required level of protection and sufficient number of auxiliary contacts.

4.4.3 Meters shall be suitable for continuous operation as per IEC 898.

4.4.4 Meter shall be suitable for 3 phase, 4 wire systems, balanced as well as unbalanced load. All instruments and associated apparatus shall be capable of carrying their full-load current without undue heating. They shall not be damaged by the passage of fault currents up to the rating of the associated switchgear through the primaries of their associated instrument transformers. The instrument meter shall be earthed by a conductor of not less than 2.5 mm2 cross-sectional area.

4.4.5 Energy meters shall be two / three element, switch board mounting type suitable for unbalanced loads. In case of two incoming feeders, a summation C.T. shall be provided with the meter.

4.4.6 The display for meters i.e. ammeter, voltmeters or multifunction meter shall be auto-ranging type.

4.4.7 Selector switches shall be inbuilt in Voltmeter such that voltmeters can read voltages between phase and phase and between phase and neutral.

4.4.8 Ammeters shall normally be suitable for 5 A secondary of current transformers

4.4.9 Voltmeter circuits shall be provided with protection through MCB as required.

4.4.10 Separate current transformers for a feeder shall be provided for protection device and for instrumentation.

4.4.11 **Current Transformers (CTs) and Voltage Transformers (VTs)**

4.4.12 CTs and VTs shall comply with IEC 61869/BSEN 61869 and CTs shall be of the epoxy resin encapsulated ring type. The ratings specified on the Drawings are indicative only and it shall be contractor/manufacturer’s responsibility to ensure that the ratings offered are adequate for the relays/meters provided considering lead resistance, etc.

4.4.13 Current transformers shall comply with approved standard and shall be compatible with and provide the necessary accuracy, over current factors, characteristics, performance and VA rating for the satisfactory operation of the relevant protection devices, instruments and meters.

4.4.14 All CTs shall have a short-time current rating as specified in IEC 60044-1.

4.4.15 CTs for protection shall be compatible with the protection relays to ensure that the CTs will not be saturated up to the maximum prospective fault current.

4.4.16 CTs designed for unit protection schemes shall be able to withstand a stability of not less than the maximum through-fault of the units.

4.4.17 In balanced circuits, the spill current with maximum stability conditions shall not exceed one quarter of the operating current of the relay.

4.4.18 CTs for use in conjunction with protection relays shall be of class 5P accuracy or better. CTs for use in conjunction with measuring instruments shall be of Class 1 accuracy. The product of rated accuracy limit factor and rated output of the protection CTs shall not be less than 20 times the total rated burden of the trip circuit including the relay, connection leads and O/C release where applicable.

4.4.19 All CTs shall have output ratings adequate to cater for the burden connected to them. The Contractor shall demonstrate to the satisfaction of the Employer representative. By calculation or by test, that each group of the CTs, when installed and having the secondary burden connected, is capable of operating the relays and other measuring instruments in accordance with the manufacturer's published characteristics and the requirements of the system, with a reasonable margin of safety.

4.4.20 Measuring CTs shall be connected to test terminal block. The test blocks shall be provided with easily removable links and designed to facilitate connection of testing instruments on load without open-circuiting the CTs.

4.4.21 The secondary circuit of each set of CTs shall be earthed at one point only through a disconnectable copper link at a readily accessible position for testing.

4.4.22 Multi-ratio CTs (where used) shall have a label clearly indicating the connections required for the alternative ratios. These connections shall be shown on panel wiring diagrams.

4.4.23 Identification labels shall be fitted, mentioning type, ratio, rating, output and serial numbers.

4.4.24 VTs shall be provided with adequately rated primary and secondary fuses.

4.4.25 Instruments shall be similar in appearance throughout the whole of the Electrical Panels. All instruments, meters shall be of flush pattern, dust and moisture proof, suitable for the environment in which they are installed.

4.4.26 All instruments and meters shall be completely segregated in instrument compartments. Compartments containing these devices shall not contain any terminals or equipment operating at higher voltages with the approval of site Engineer.

4.4.27 The housing shall be of steel or phenolic mould. Design and manufacture of meters shall ensure prevention of fogging of instrument glass. Selector switches shall be provided for ammeters and voltmeters used in three-phase system. This selector shall be of built-in type with meters.

4.5 RELAYS

4.5.1 The relays are having in-built function with protective gears such as ACB, MCCB and MCB and MPCB etc. In case any relay is required for additional protection as stated in BOQ or otherwise, the same shall be provided to ensure full protection to the system.

4.6 EMERGENCY PUSH BUTTON (EPB)

4.6.1 Emergency lock and key type push buttons shall be installed wherever required or specified in BOQ to de-energize the Electrical Panels in the event of an emergency. The EPB shall be button type with flat surface protection guard ring and pressed-in design with key reset so that accidental triggering and vandalism shall be avoided as far as possible. Transparent hinged cover shall be provided in front. Unless otherwise specified on the Drawings, the EPB shall be mounted at 1300 + 100 mm above finish floor level. The button design and the installation details shall be submitted for approval.

4.7 INTERLOCK AND PADLOCKING FACILITIES

4.7.1 Mechanical key interlocks shall be provided wherever applicable or as specified in BOQ and shall be so designed as to avoid mal-operation at the point of manual application. The scheme shall be such that attempts to remove a captive key shall not result in tripping or opening of the device.

4.7.2 The tripping of the ACB(s) shall be via local hard wiring control and in Signal(s) shall also be generated from circuit breaker(s) upstream of the corresponding Electrical Panels and the switchboard interconnected section ACB.

4.7.3 Electrical interlocks on withdrawable equipment shall be so arranged that if the equipments are withdrawn, the complete operation of the withdrawn equipment shall be independent of the remote interlocking contacts. In addition, interlocks shall not be defeated leading to damages or unsafe operations of Electrical Panels due to the withdrawing of equipment.

4.7.4 Locking facilities shall be provided where appropriate for switches and isolators in order that they may be locked in the open position. Switchgear cubicle access doors shall be equipped with integral type locks, preferably incorporated in the handles of the equipment.

4.7.5 Where locking facilities are of the integral barrel type, the key for each lock shall be unique to the associated lock unless otherwise specified.

4.7.6 Two keys shall be provided for every lock supplied. The keys shall be fitted with rings with identification labels, and cabinets with glazed front- opening doors shall be provided. The cabinets shall be adequate in size and equipped with hooks to house all keys when not in use, and shall be mounted in positions to be decided.

4.8 INTERNAL AND CONTROL WIRING

4.8.1 All equipment shall have adequate provision for the entry and termination of all associated power and auxiliary cables.

4.8.2 Cable entry shall in all cases, except where otherwise specifically approved, and be at the base of the equipment. All cabling and wiring within the Electrical Panels shall be neatly run and fitted in or upon such cable trays, trunkings and conduits as may be appropriate to the layout and equipment. Cable trays, trunkings, conduits and cleats shall be non - metallic and shall be of the low smoke halogen free material. Metallic cleats is acceptable with the approval of the site Engineer.

4.8.3 LSZH and Fire Survival Cables shall be as specified in cable specification Section (BS 6724-multicore cable and BS 7211 for single core cable). All internal and control wiring shall be Low Smoke Zero Halogen (LSZH) copper conductor wires rated at 450/750 V complying with BS 7211 for this Specification. All control wiring within the Electrical Panels shall be with single core minimum 2.5 mm2 for CT and balance as per approved manufacturer design. Insulation shall have a glossy finish, be resistant to oil and be incapable of supporting combustion. Fire Survival wires shall be provided as per BOQ.

4.8.4 Wiring from the fixed part of the switchboard to the movable part such as hinged door shall be enclosed by flexible tubing made of Low smoke Zero Halogen material. Exposed live terminals shall be suitably shrouded or covered.

4.8.5 Wiring passing out to fully accessible positions shall be run in non-metallic low smoke halogen free flexible tubes or conduits.

4.8.6 All internal wiring shall be neatly run and securely fixed in non-metallic cleats in such a manner that, wherever practicable, wiring can be checked against diagrams without removal of the cleats.

4.8.7 Access opening shall be fitted with a suitable long lifegrommet where inter-panel wiring passes through panel side sheets etc.

4.8.8 Bus-wires shall be fully insulated. Bus-wires terminals shall be fully accessible from the point of entry to each enclosure. MCB and links shall be provided to enable all control circuits within the Electrical Panels to be isolated from the bus-wires.

4.8.9 All control circuits shall be protected by a MCB.

4.8.10 There shall be no joint in conductors between terminal points.

4.8.11 Terminations for terminals shall be of the crimped-on ring type. Terminations of stranded conductors to clamp type terminals shall be of the crimped-on solid rod type.

4.8.12 No more than one core of either internal or external wiring shall terminate on any outgoing terminal. Where duplication of terminal blocks is necessary, suitable solid bonding links shall be incorporated in the design of block selected.

4.8.13 Wiring for all known future equipment shall be provided and all wires shall be terminated.

4.8.14 All wires between the terminals of two equipment shall be given a unique number according to an approved system. A wire number shall not change solely by virtue of passing through, say, a marshalling terminal block.

4.8.15 In the interests of uniformity, the wire-numbering system shall be approved by the Engineer.

4.8.16 Identification markers shall be fitted to all wires and multicore cable tails within enclosures in accordance with the diagram for apparatus concerned. Cable and core makers shall be of insulation material, colored according to the wire numbering system with a glossy finish, be resistant to oil and be incapable of supporting combustion. Numbers shall not be duplicated unless the corresponding wires are directly in series or parallel

4.8.17 Different insulation colours shall be provided to distinguish the various circuits. All wiring shall conform to the colour and ferrule codes to be approved by Engineer.

4.9 TERMINAL BLOCKS

4.9.1 Both incoming and outgoing cable shall have top or bottom entry depending on site requirement.

4.9.2 Each terminal block compartment shall have not less than 20 % or 4 spare terminals whichever is greater.

4.9.3 Terminal blocks for low voltage wiring shall be moulded from high-grade non-hygroscopic melamine, comprise bank of rail-mounted blocks with all live parts fully shrouded, screw- clamp, spring loaded insertion, solder-lug or stud type terminals as appropriate to the design and duty of the cables to be terminated. Pinch-type screws, where the screw is in direct contact with the conductor, shall not be used.

4.9.4 Each terminal shall be provided with claw-type washers, crimp lugs or other approved means for connection of the wires. Plain and spring washers, nuts and lockouts shall be electro-tinned.

4.9.5 Terminals shall be assembled in banks and each terminal shall be complete with marking tags to fit into moulded tag slots.

4.9.6 Terminals for final connections for indication, instrumentation and metering circuitry shall have test probe facilities and an integral disconnecting device to facilitate testing.

4.9.7 Terminations shall be grouped according to function and no more than two wires Connected to one terminal. Labels shall be provided adjacent to the terminal block to identify the function and voltage of each group.

4.9.8 All terminals to which 240 V or 415 V AC circuits are connected, where they are in individual terminal blocks, shall be provided with a transparent insulated cover which in addition to any other form of identification and shall have a label engraved suitably indicating the voltage.

4.9.9 Terminals for the control supply which may be still alive when the main equipment is isolated from the mains supply shall be suitably labelled to reduce the risk of accidental contact.

4.9.10 All terminals shall bear a permanent identification number or letter.

4.10 MARSHALING UNIT

4.10.1 In main distribution Electrical Panels separate marshalling chamber shall be provided for BMS interfaces terminals or wherever required as per BMS requirement.

4.10.2 Single location interface for different LV components of main distribution panel (DB100, DB200) or other Electrical panel where ever necessary or as per BOQ shall be provided through marshalling chamber for BMS interface.

4.10.3 All interface terminals and ports for BMS shall be wired up to the marshalling chamber. Necessary marking and ferruling shall be provided for individual termination.

4.10.4 Control command interface and other terminals having potential should have due separation from VFC interface terminals. Control and signal cable wiring from different relays, sensors, transducer, controller and contactor releases shall be through separate wiring bunch to avoid fault current or external magnetic/ electric interface.

4.10.5 Necessary multi dropping and single point interface provision shall be done through suitable short links. Communicable devices using standard protocol communication shall be looped as per BMS requirement.

4.10.6 Marshalling chamber should have provided with necessary mounting arrangement or space provision for BMS remote I/O module/ PLC equipment along with its associated interface equipment and power supply unit or as per BOQ.

4.10.7 Connecting cable with connector between ACB communication unit and junction box shall be provided.

4.10.8 24V DC source unit or as required (Incoming supply shall be taped form the control supply available in the panel) for communication of ACB/MCCB with SCADA/BMS system.

4.10.9 Panel manufactures shall provide the required termination and interface detail for BMS work. In case of requirement of supervision and guidance during BMS commissioning, same shall be inclusive to the panel manufacture's scope of work. It is the responsible of panel manufactures to provide necessary interface detail such as data point register address during BMS commissioning or supervise as appropriate during installation and testing of BMS system.

4.10.10 Marshalling box shall comply with EMC (electromagnetic Compliance) and protected from any electrical or magnetic interface. Required protection against any BMS or panel component has to be inclusive to respective contractor's scope of work.

4.10.11 Any specific interface requirement not specified here with shall be wired upto the marshaling chamber interface terminal. BMS/SCADA interface point should only confine to marshalling box.

4.11 BMS INTERFACE

4.11.1 Electrical contractor shall cross reference the requirement of BMS remote control and monitoring interface as required for electrical equipments and shall provide the necessary volt free contact and remote control interface for BMS.

4.11.2 Serial interface as applicable for ACB/MCCB and digital meters or MFMs shall be strictly on standard protocol communication (preferable with MODBUS-RTU, RS485, 2 wire communication). Necessary interface detail and drawing shall be provided to BMS contractor during commissioning.

4.11.3 All terminals and BMS interface terminal and ports shall be wired to a separate chamber with adequate number of ITBs and with proper marking as per interface document.

4.11.4 No such change in contact or pseudo signal shall be provided for critical alarms control interface.

4.11.5 BMS and PLC interface for control command shall be pulse type close contacts for single command output / double command output or a variable voltage/current (i.e. 0V- 10V or 4mA - 20 mA) for analog output command.

4.11.6 There shall be one interface for control open and one for control close operations. The Contractor shall provide appropriate equipment to sense and latch the remote control signal for performing the open/close control function. The BMS digital output (DO) &analog output (AO) signal shall be as stipulated.

4.11.7 Contacts shall be rated to adequately make and break and carry continuously not less than 5A at 250V AC or 2A at 11O V DC.Volt-free contacts for sequence of event (SOE) and alarms shall firmly close and seat in position once activated. The contacts shall not bounce or vibrate due to internal or external causes

4.11.8 Required data point as per BMS requirement shall be configured in respective controller or equipment by panel manufactures as required with necessary hardware and software for above said serial link communication.

4.12 INDICATING LAMPS

4.12.1 Indicating lamps shall be multiple LED type. All indicating lamps shall be suitably rated so that the indication is clearly visible from the side and front at a distance of not less than 3 m in a room.

4.12.2 The colours of indicating lamps for red, yellow, blue phases, ACB on, off and trip shall be red, yellow, blue, red, green and amber respectively.

4.13 LOW VOLTAGE SWITCHGEAR

4.13.1 AIR CIRCUIT BREAKERS

4.13.1.1 ACB should be mechanically robust of compact design, air break horizontal and withdrawable type, confirming to IS/IEC 60947-2 and EN 60947-2.

4.13.1.2 Air Circuit Breaker is provided in transformer incomer, outgoing feeder, Interconnector Bus-Section and essential/semi-essential circuit breaker as defined in BOQ.

4.13.1.3 Manual charging as well as by 240 V AC motor with charged spring closing mechanism complete with anti-pumping relay, discharge resistor, auxiliary switch, etc.

4.13.1.4 240 V A.C shunt-trip coil shall be operable, within operational voltage range of 70% to 110% of rated voltage as per Clause 7.2.1.3 of IEC 60947-1.

4.13.1.5 The operating mechanism shall be trip-free.

4.13.1.6 Maximum number of circuit breaker auxiliary switches, spare auxiliary switches to be equally divided between normally open and normally closed. At least 4 spare pairs of N.O. and N.C. volt free contacts shall be provided.

4.13.1.7 Indicating lamps for on, off, tripped on fault and trip supply healthy with all necessary push buttons, panel wiring, bus wiring, terminals, fuses, etc.

4.13.1.8 Power and control cable terminals with undrilled gland plates for outgoing power cables and multi-core cables.

4.13.1.9 Electrical connection between the breaker and switchboard shall be of plug and socket type with automatic screening shutters. An interlock to prevent withdrawal when the breaker is closed.

4.13.1.10 Number of Poles shall be as per BOQ.

4.13.1.11 Local/auto control selecter switch shall be lockable in all positions. The automatic control shall be defeated when the selector switch is put at local or OFF position as per drawing and BOQ

4.13.1.12 Remote indication and alarm facilities shall be provided for Circuit-breaker open, Circuit-breaker closed, Circuit Breaker is ready to close, Circuit-breaker tripped on fault, and Switch position of local/remote control selector switch.

4.13.1.13 **Control switch for air circuit breakers shall be as follows:**

4.13.1.13.1 Air Circuit breakers shall be fitted with operative switches of the pistol grip type. The handles of control switches for air circuit breakers shall turn clockwise for closing and anti - clockwise for tripping.

4.13.1.13.2 The control switch shall be clearly labelled as CIRCUIT BREAKER OPEN - NEUTRAL - CLOSE, with spring return to the neutral position. Mechanical interlock shall be fitted to prevent repetitive closing without moving first to the trip position, and shall be capable of padlocking in the neutral or trip position.

4.13.1.14 **Set of terminals wired to provide for connection to the following:**

4.13.1.14.1 Automatic changeover and interlocking as shown on the drawing

4.13.1.14.2 Operation of emergency push button as per requirement or as per BOQ.

4.13.1.14.3 Signal cables wired to terminal block for remote monitoring to SCADA.

4.13.1.15 **Electrical Characteristics:**

4.13.1.15.1 Rated Insulation Voltage: 1000 V

4.13.1.15.2 Rated Frequency: 50 Hz

4.13.1.15.3 Rated ambient temperature: As per Clause 6.1.1 and 6.1.3 of IEC 60947

4.13.1.15.4 Utilization category: B or as per drawing or BOQ.

4.13.1.15.5 Rated uninterrupted current: as shown on Drawings, however the contractor must provide breaker after taking into account of the installation conditions and derating for ambient temperature, based on selected make during preparation of working drawings.

4.13.1.15.6 Current Ratings shall be as follows:

4.13.1.15.6.1 Rated short-time withstand current (Icw): 70/65/50 kA for 1 second (minimum)

4.13.1.15.6.2 Rated ultimate short circuit breakigcapacity(Icu): 70/65/50 kA based on actual fault level or as per BOQ.

4.13.1.15.6.3 Rated service short-circuit breaking capacity (Ics): 100% of Icu, and

4.13.1.15.6.4 Rated short-circuit making capacity: shall be atleast 2.1 times of ultimate short circuit breakig capacity at 0.25 power factor or as per BOQ.

4.13.1.16 Protection

4.13.1.16.1 ACB shall have microprocessor based protection releases for type of faults with selective over current (long time, short time & instantaneous) & earth fault protection, measurement of electrical parameters and with communication capability with SCADA/BMS system. Any other additional protection as mentioned in BOQ. ACB shall have an LED/LCD display to show true RMS current in all the three phases and highest current among these phases. The release shall be equipped with self diagnostic feature with indication. The release shall have zone selective interlocking and be capable for communication through Modbus over Serial (RS 485 port) as per the requirement of design or as defined in BOQ. The overload and short circuit characteristics should be front adjustable and password protected.

4.13.1.16.2 The release should have an internal fault indication for faster fault diagnosis/self diagnostic feature is required.

4.13.1.16.3 The release should have fault indications by which discrimination of fault is possible.

4.13.1.16.4 Control relays and wiring for automatic changeover interlocking and other breaker operation as shown on the Drawings.

4.13.1.16.5 Fire resistant transparent covers shall be provided over ACB's to achieve IP-54 protection and door interlock so that ACB access door shall not open if ACB is ON otherwise it will automatically OFF if Door is opened.

4.13.1.16.6 Electrical interlock for the two incoming circuit breakers and interconnector bus - section circuit breaker to prevent paralleling of different power supply sources at any one time as shown on the Drawings

4.13.1.16.7 Following shall be provided for ACB connected to the transformer incomer:

a) Four Protection Current Transformers (three in panel, one in loose to be mounted in transformer neutral), a Restricted Earth Fault Relay and a Standby Earth Fault relay as specified for the interface with high voltage switchgear.

b) Two ways inter-tripping relay shall be provided with the associated HV feeder circuit breaker by interfacing with the Power Supply Contactor.

c) Voltage sensing relay and associated relays for automatic changeover and interlocking operation as detailed on the Drawings.

4.13.1.16.8 Interlocks and Test Operation Facilities

All ACBs shall be provided with interlocks to ensure that:

a) The ACB cannot be plugged in or isolated while it is closed,

b) The ACB cannot be closed until it is fully plugged in or completely isolated

c) The ACB cannot be closed in the service position without completing the auxiliary circuits between the fixed and moving portions

d) With manual charged and motor charged spring mechanisms the springs cannot be discharged until they have been fully charged and until the means for charging has been removed or disconnected,

e) Facilities shall be provided for testing the ACB operation when in the isolated and withdrawn positions by the normal means as in service, and

f) Where control circuits are provided and interlock circuits are broken via plugs on withdrawal of the ACB, a minimum of one jumper lead and plug assembly of each size and type shall be provided to facilitate testing in the withdrawn position.

g) The neutral shall be rated for 100%

4.13.1.16.9 Safety Shutters

4.13.1.16.9.1 A set of shutters with padlocking facilities shall be provided to cover each three phase group of stationary isolating contacts. The shutters shall be independent and operated automatically by a positive drive from the ACB withdrawal mechanism

4.13.1.16.9.2 In order to prevent unauthorized operation, the withdrawable air circuit breakers shall be provided with padlock facilities to secure them in their connected, test and isolated positions.

4.13.2 MOULDED CASE CIRCUIT BREAKERS

4.13.2.1 MCCBs shall comply with and be type-tested to IS/IEC 60947-2 or EN 60947-2. Each MCCB shall be of fixed or withdrawable type, as specified in the BOQ and have all the mechanical and live parts completely enclosed in an insulated moulded case. Withdrawable pattern circuit breakers shall be designed that their electrical equipment can be safely disconnected from or connected to the main circuit whilst the circuits are live.

4.13.2.2 MCCB shall be suitable for isolation as per Annexure 7.1.2 of IEC 60947-2

4.13.3 MCCBs shall meet the following requirements:

a) Number of poles: double-pole, triple-pole or four poles as specified on theDrawings or Design or BOQ

b) Rated operational voltage: 240 / 415 V AC, as per drawing or BOQ

c) Rated insulation voltage: 660 V AC, higher voltage acceptable

d) Rated uninterrupted current (In): as shown on the Drawings or BOQ, but after taking into account the installation conditions and temperature deration.

e) Rated frequency: 50 Hz,

f) Rated short-circuit making capacity (Icm): shall be at least 2.1 times of ultimate short circuit breaking capacity at 0.25 power factor,

g) Rated ultimate short-circuit breaking capacity (Icu): 65/50/35 kA (min),

h) Rated: service short-circuit breaking capacity (Ics): 65/50/35 kA Further, Ics must be equal to 100% Icu for the selected breaker,

i) Utilization category: A or B as appropriate,

j) Degree of protection: IP 3X to IEC 60529 or EN 60529, and

k) Rated ambient temperature: As per IEC 60947-2

l) Impulse Withstand Voltage - 8KV

m) 0 - t - CO - t - Co type of Duty i.e. Ics=Icu.

4.13.3.1 MCCB’s to be provided in LV Main Switchboard shall be stored energy type motorized and Suitable for Remote Closing by BMS.

4.13.3.2 All MCCB’s should have front adjustable microprocessor based releases with adjustment in the range of 40 - 100% for nominal overloads and adjustable setting for short circuit faults. MCCB’s for network/feeder Protection shall have releases with earth Fault Protection features, wherever and as indicated in Bill of quantities or drawings.

4.13.3.3 In case of 4 pole MCCB, neutral shall be defined and capable of offering protection upto full rating with possibility of adjustment at site in the neutral setting.

4.13.3.4 Mechanical endurance shall be as specified in latest IEC standard.

4.13.3.5 MCCB’s shall have an electrical endurance operation cycles as per latest IEC standard 60947.

4.13.3.6 All MCCB’s shall be arranged for padlocking in OFF positions with lock provided. A shunt trip coil shall be provided to facilitate automatic tripping and local manual tripping. The manual trip device shall be fitted with the means of padlocking. The shunt trip coil shall be suitable for operation within a voltage range of 70% to 110% of the rated AC power supply voltage.

4.13.3.7 Electronic trip units shall comply with the requirements as specified in Appendix F (EMC /EMI Compatibility) of IEC 60947-2 or EN 60947-2.

4.13.3.8 The trip unit shall be easily replaceable in the same MCCB without changing the MCCB.

4.13.3.9 The time delay on overload tripping shall be inversely proportional to the over current up to a threshold value of approximately six to seven times the rated current at rated working temperature.

4.13.3.10 Handle position shall give positive indication of ’ON’ ‘OFF’ or ’TRIPPED’, thus qualifying to disconnection as per IEC 60947-3 indicating true position of all the contacts.

4.13.3.11 The operating mechanism of MCCB’s shall be Independent of the operating speed of the over centre toggle and the MCCB shall be of current limiting type and comprise of Quick make and Quick break switching. Contacts shall be non-welding type. The operating mechanism should be trip-free and provided with mechanical “ON", OFF" and "TRIPPED indicator. The MCCB shall be designed for both vertical and horizontal mounting, without any adverse effect on electrical performance.

4.13.3.12 Remote closing and tripping coil should be of continuous duty cycle.

4.13.3.13 MCCB’s shall have common field fittable auxiliaries for the entire range and above 250 A the accessories like copper spreaders and phase barriers should be the integral part of the MCCB’s.

4.13.4 **MINIATURE CIRCUIT BREAKERS (MCB)**

4.13.4.1 MCBs shall comply with and be type-tested to IEC 60898 or EN 60898.

4.13.4.2 MCBs shall meet the following requirements:

a) Number of poles: single-pole, double-pole, triple-pole or four-pole as specified in the BOQ or Drawings

b) Protection against external influences: Enclosed-type,

c) Method of connection: Bolted type or clip-on type,

d) Rated operational voltage and frequency 240 / 415 V AC and 50 Hz.

e) Rated current: 6 A, 10 A, 16 A, 20 A, 25 A, 32 A, 40 A, 50 A, as shown on the Drawings. Above 50A, MCCB as specified above must be used.

f) Range of instantaneous tripping current: MCB's shall be current limiting Type Class 3 with range of instantaneous tripping current B, C or D type as appropriate oras specified,

g) Rated short-circuit breaking capacity: not less than 10 kA (M3) unless otherwise specified in BOQ

h) I^2t characteristic: suitable for load and circuit being protected,

i) Degree of protection: IP-20 for MCB's

j) Reference ambient temperature: as per IEC 60898.

k) MCB's shall have minimum power loss (Watts) per pole as per the IEC and should be proven by published value by manufacturer.

4.13.4.3 The load handling contacts shall be silver/tungsten or proven material and the contacts and operating mechanism shall be designed so as to give a wiping action both at make and break. Thebreaker operating mechanism shall be of trip-free type. The breaker operating dolly shall be clearly indicated for the "ON" and "OFF" positions. It should be of Quick make and Quick break type.

4.13.4.4 Circuit protection against overload and short-circuit conditions shall be provided by means of thermal-magnetic device. Double-pole, triple-pole, and four pole MCBs shall be integral units and interlocked internally so that an over current through any pole shall trip all the poles of the MCB simultaneously. An assembly of two or three or four single-pole units mechanically strapped together is not acceptable.

4.13.4.5 Housing shall be heat resistant and having high impact strength. All DP, TP and FP circuit breaker shall have a common trip bar and should be mechanically coupled through a pin. It shall have an electrical endurance of the order of 10000 operation cycle for currentrating of up to 50A.

4.13.5 RESIDUAL CURRENT CIRCUIT BREAKER

4.13.5.1 RCCBs shall be double pole or four-pole current-operated, housed in a totally enclosed moulded case, manufactured and tested in compliance with IEC 61008 or EN 61008.

4.13.5.2 RCCBs shall meet the following requirements:

a) Number of poles: double-pole or four-pole as specified on the Drawings,

b) Rated current (In): as shown on the Drawings,

c) Rated residual operating current: 30 mA or 100 mA or 300 mA as shown on drawings or as per approval of the Engineer.

d) Rated voltage: 240/415 V AC,

e) Rated frequency: 50 Hz,

f) Rated short-circuit capacity: not less than 1.5 kA unless otherwise specified in BOQ

g) Operating characteristics in case of residual currents with DC components: as specified,

h) Method of mounting: distribution board type,

i) Method of connection: connection shall be made with propre size of thimbles and number ferruling for circuit identification,

j) I^2t characteristic: suitable for equipment and circuit being protected

k) Degree of protection: IP 3X to IEC 60529 or EN 60529, and

l) Reference ambient temperature: As per IEC.

4.13.5.3 The tripping mechanism shall be of trip-free so that the unit cannot be held closed against an earth fault. Tripping devices utilizing electronic amplifiers or rectifiers are not acceptable.

4.13.5.4 Provision shall be made for testing the automatic earth - leakage tripping by an integral test device. A device shall be fitted for prevention against reclosing after the device has tripped on earth leakage.

4.13.6 RCBO (RESIDUAL CURRENT CIRCUIT BREAKER WITH OVER-CURRENT) PROTECTION

4.13.6.1 RCBOs shall be double pole or four-pole current-operated, housed in a totally enclosed moulded case, manufactured and tested in compliance with IEC 61009 -1, IS 12640(part 2) 2008 and ISI marked.

4.13.6.2 RCBOs shall meet the following requirements:

a) Number of poles: double-pole or four-pole as specified on the Drawings,

b) Rated current (In): as shown on the Drawings,

c) Rated residual operating current: 30 mA or 100 mA or 300 mA as shown on drawings or as per approval of the Engineer.

d) Rated voltage: 230/415 V AC,

e) Rated frequency: 50 Hz,

f) Rated short-circuit capacity: 10kA

g) Operating characteristics in case of residual currents with DC components: as specified,

h) Method of mounting: distribution board type,

i) Method of connection: connection shall be made with propre size of thimbles and number ferruling for circuit identification,

j) I^2t characteristic: suitable for equipment and circuit being protected

k) Degree of protection: IP 2X, and

l) Reference ambient temperature: As per IS 12640-1

4.13.6.3 The tripping mechanism shall be of trip-free so that the unit cannot be held closed against an earth fault. Tripping devices utilizing electronic amplifiers or rectifiers are not acceptable.

4.13.6.4 Provision shall be made for testing the automatic earth - leakage tripping by an integral test device. A device shall be fitted for prevention against reclosing after the device has tripped on earth leakage

4.13.6.5 A mechanical flag indicator on RCBO for faster identification of fault trip condition i.e. earth leakage or over-current for faster fault diagnosis and preventive measures.

4.14 DESCRIMINATION

4.14.1 Selection of ACB, MCCB and MCB shall be of same make. Total discrimination up to the design fault level must be available between the various elements of switchgear (ACB, MCCB, MCB etc) selected. Supplier must provide test certificates from acceptable, accredited and reputed laboratories or submit published discrimination charts/tables to prove the same. In view of Standardization and Uniformity, mixing of two series of switchgear (even from the same manufacturer) for either MCCB or ACB will not be permitted.

4.14.2 In case higher frame sizes rating of switchgear(than those specified In the BOQ) is required to be provided to achieve the above requirement, due to selection of a particular make, the same shall be provided at no extra cost if other makes are able to achieve the same with the specified frame size.

4.15 REMOTE MONITORING

The following critical status and alarms for each Electrical Panels shall be sent to BMS for remote monitoring via volt-free contacts or serial interface over standard protocol communication as approved but not limited to:

a) Individual ACB/MCCB open/close status,

b) Common alarm for ACBs/MCCBs trip on fault/lock out,

c) Common alarm for any local/remote or local/auto selector switch in local mode

d) Control supply failure,

e) ACB ready to close indication.

f) Emergency push button (EPB) operated, and

g) Busbar voltage ,current , frequency and energy parameter

h) Electrical Panels under voltage alarm and cause of tripping.

4.16 MOTOR STARTER

4.16.1 Every motor starter shall be designed to perform the following functions efficiently and safety:

a) To start the motor without damage to the drive or driven equipment whilst regulating the starting current to the satisfaction of the requirements of this Specification and ensuring that at all stages of starting, the motor will develop sufficient torque to accelerate the load.

b) To stop the motor.

c) To prevent damage to the motor due to overload, disconnection of one phase etc..

d) To prevent damage to reduced and danger to personnel due to resumption of the electricity supply following a failure.

e) To prevent the damage to the motor due to stalling or internal electrical or mechanical faults by quickly disconnecting the supply.

f) To prevent damage to the motor or the starter itself due to improper, unskilled or hesitant operation or failure to complete a starting sequence once it is connected.

g) To enable the motor and starter to be completely isolated from the main supply and from all control supplies for inspection and repairs by means of fixed type unit for each starter circuit.

4.16.2 Each motor starter assembly shall comprise MCCB/MPCB, contactors, protection relays, electronic circuitry, control switches, lamps and instruments and accessories as specified hereinafter. It shall include control devices for automatic control systems. The whole unit shall be enclosed in the cubicle, from which no access can be gained to adjoining cubicles.

4.16.3 The specified starter types are based on estimated motor ratings. The final selection of starter shall be based on the installed motor rating. Starters and associated over-load devices shall be selected in accordance with the run-up time of the associated motor driven load, the maximum thermal capacity of the motor and frequency of starting, and the duty cycle. All starters shall have suitable protection for phase-to-phase, phase-to-neutral and phase-to-earth faults, over-loads, and single phasing, with additional protection measures as specified. Overload relays releases as specified shall have inverse time delay characteristics compatible with the motor drive to which they are applied for all protective devices the short-circuit capacity (Isc) shall be capable of withstanding a fault current of the panel, as a minimum. The specifications of incoming and other circuit breakers (ACB/MCCB etc.) shall be as per clause 4.13, as relevant.

4.16.4 All starters shall be in accordance with section 7.2 of IEC 60947-4-1 or EN 60947-4-1, and shall be adequately rated for conditions in which it shall operate.

4.16.5 All starters shall be type tested by a competent and internationally recognized testing authority for type 2 co-ordinations in accordance with IEC 60947-4-1 or EN 60947-4-1.

4.16.6 All contactors shall be electro-magnetic type with utilization category AC - 3 to IEC 60947-1.

4.16.7 All starter shall be of electrically held on pattern and shall not release until the over voltage falls below 70% of nominal.

4.16.8 Control circuits shall generally be operated on main supply derived from the LMCP, suitably protected by MCB type 2, as specified in clause 4.13. The control circuit shall be of self-holding and latching design.

4.16.9 Where the control voltage is not 240V it shall be derived from transformers to BS 3535/BS 61558. Transformers shall be rated at the total control circuit load plus a minimum of 10% spare capacity. Transformer primary windings shall be protected by MCB’s in the line connection(s) and a removable neutral link shall be provided where the neutral is required. The supply shall be taken from downstream of the main incoming Circuit Breaker. One end of the transformer secondary shall be connected directly to the main earth bar. This connection shall be upstream of the control circuit neutral link.The supply from the other end-of the winding shall be protected by MCB.

4.16.10 The type of starters for other mechanical equipment such as plumbing, drainage, fire services pump and other motor circuits shall be as specified in this clause subject to rating of the motors selected during working drawing production as per clause 4.16.3. The starters shall also comply with the requirements laid down in the Code of Practice of electricity(Wiring) Regulations. Voltage for motors shall be 415V 3-phase or 240V 1-phase, as required. Motors rated 0.37kW and larger shall have a rated voltage of 415V, 3 phase, 50Hz. Motors rated smaller than 0.37 kW shall be operated at 240V 1-phase. Direct-online motor starters shall be used for motors up to and including 3.75 kW at 415 volts, 3 phase. All motors over this limit shall be equipped with reduced voltage starters of the star-delta or soft starter type as indicated in BOQ.

Motor size (M) Load	Maximum starting current in multiple of full load current (phase of motors)
M≤ 0.37 kW	6 (single phase motor)
0.37 kW< M< 3.75 kW	6 (three phase motor)
3.75 kW ≤ M	6-7 (three phase motor)

(Tolerance in the above currents shall be of the order of ±20%)

4.16.11 The direct-on-line starters shall be provide based on condition given in Clause 4.16.10 and shall include, but not be limited to, the following:

a) MPCB as specified,

b) Triple pole air break contactor,

c) MPCB wherever specified or required shall be provided with inbuilt Thermal/Magnetic and single-phasing protection. MCCB, wherever specified/ required shall be of Electronic Trip Unit type with single phasing preventer unit.

d) All Current transformers with suitable ratio, output and accuracy for motor protection,

e) Local/off/remote control selector switch lockable in each position,

f) Set of start and stop push button,

g) Set of indicating lamps for motor running, off and tripped on fault,

h) Set of digital input (dry contacts) interface wired to terminals for wiring connection to station building services controllers,

i) One set of terminals wired to the following:

   a. Emergency stop push button, effective in all positions of the local/remoteswitch if any.

   b. Remote start/stop of the motor, effective only in the remote position of the selector switch.

   c. Hour run meter,

   d. Lamp test button,

   e. Any other items required to affect satisfactory motor starting and control asspecified in this Specification, and

   f. double pole contractor and motor protection unit for single phase DOL type starter.

j) Interposing relays/contactor for remote close and remote open whenever required.

k) Leakage Protection for DOL starters shall be provided with 25 / 40 A, 4 Pole RCCB with sensitivity of 100/300 mA as specified.

4.16.12 Based on criteria given in Clause 4.16.10 or wherever specified on the Drawings, star-delta starters shall be provided to limit the maximum starting current within 2.5 times the rated motor full load current. The star-delta starters shall be equipped as per direct-on-line starters specified above, with the following additional provisions:

a) Star-delta starters shall be of the automatic type and shall comply with BS EN60947-4-1. Triple pole air break star and delta contactors shall be electrically interlocked so that they cannot close or be closed at the same time. In all types ofstar-delta starters the correct phase relationship between the star and delta connections to minimize disturbance on changeover shall be maintained.

b) rated and adjustable solid state timer for automatic star-delta transition, and

c) Automatic changeover timers shall be adjustable from 1 second to 30 seconds. Timers shall incorporate a fixed delay of between 20 ms between the star contact or opening and the delta contactor closing.

d) MPCB /MCCB as specified in drawings /Schedules shall be used. MCCB shall be as specified in clause 4.13 with the difference that the Electronic trip Units shall be suitable for Motor Protection against Over Load (Adjustable) and Short Circuit. For requirement of Earth fault/Earth Leakage protection, Clause 4.16.15 referred to.

Soft Starters

(a) All soft Starters shall be complying with class A for conducted and radiated emissions, described in the Standard EN/IEC 60947-4-2. Class B can be obtained with additional accessories and covers only soft starters with a rated current not exceeding 170 A.

(b) The Soft-starter shall comply with UL 508 and CSA "Industrial Control Equipment”.

(c) All soft starters shall be equipped with motor current measuring means to ensure engine protection The soft starter should have a separate power control.

(d) The terminals of the board control shall be of plug type.

(e) The soft starter shall be able to operate at design ambient temperatures from -10 to + 40 °C without derating, and between 40 and 60 ° C with suitable derating factor shall be considered.

The maximum relative humidity will be 95% without condensation or dripping water according to standards IEC60947-4-2.

The storage temperature can be between -25 °C to + 70°C

Soft Starter Cooling should be manage automatically.

Voltage variation	-15% to +10 %
Frequency Variation	+/-5%

(f) Starter shall be protected against Thermal overload, reverse phase network, loss of phase, external faults, over current, short circuit faults etc.

(g) Access of setting should be protected by locked by code or other functions.

(h) Starter shall be handle the by-pass of soft starter, manage the closure of the by-Pass at end of acceleration time and open that by-Pass at end of stop sequence.

(i) Starter shall be monitoring following information on screen

Motor Current

Torque

Active Power

Current Status (acceleration, decelaration, etc.)

Operating time.

The last fault occured

4.16.13 **Reversing Starters**

Forward and reverse contactors will be mechanically and electrically interlocked. Reversing starters will be in accordance with BS EN 60947 and be suitable for AC 4 utilization category.

4.16.14 **Incoming Supplies**

The isolation devices for assemblies with duplicated supplies shall be interlocked(electrically and mechanically) to prevent simultaneous closure.

4.16.15 **Earth Leakage/Earth Fault Protection**

For Earth Leakage /earth fault Protection for Circuits with Star-delta starters (wherever required, based on calculations done during working drawings Production Stage). Add- on Modules to MCCB (based on current rating of MCCB) shall be provided with continuous adjustment from 30 mA to 10 A range with adjustable time delay.

4.16.16 **Status/Alarm**

a) Indicating lamps shall be provided on each phase of the main incoming supply.

b) All assemblies incorporating automatic control systems shall be equipped with suitable status/ alarm annunciation facilities. If these are not available directly from the automatic control system then a separate status/alarm annunciator shall be provided. Status/alarm enunciators shall provide indications for all starting devices of ’ON’, ’OFF’and ’TRIPPED’ conditions.

c) The status/alarm annunciator equipment shall be mounted in the same cubicle as the automatic controls. Volt-free contacts shall be provided for each condition in each starter cubicle, which shall be wired internally to the status/alarm annunciator, via terminals at each end.

d) The schematic diagrams as indicated in the Working Drawings shall be shown and the operating status of all equipment shall also be indicated. Status indicating lights shall exhibit run/stop or open/close and fault conditions. The Contractor shall provide test buttons for the indicating lights. The layout, color, symbols and arrangement of the mimic diagram shall be submitted to the Engineer for review prior to manufacture.

e) Suitable interfaces shall be built into each channel to relay signals to remote locations, by means of volt-free contacts.

f) Hours-run meters shall be fitted as specified and not be resettable.

4.16.17 Control Circuits

a) In each individual starter, the control circuit shall be provided with MCB, a neutral link, a means of disconnection and, where specified, a disconnection over ride switch.

b) Neutral links shall comprise a solid copper link mounted in a white coloured fuse base and carrier, which shall not be interchangeable with control or power fuse carriers.

c) The control circuit supply shall be connected via an auxiliary contact on the starter isolator.

d) Where automatic changeover systems are specified for duty/standby operation, the control circuit for the changeover controls shall be independent of both starters.

e) Start delay timers shall be incorporated for sequential operation of starters where specified. The failure of one timer or starter to operate shall not prevent operation of the remaining starters.

4.16.18 Interlocking

a) The control circuit of a dependent starter shall be wired via auxiliarymotor cootactor in the lead starter. In the case of reduced voltage starter, the contacts shall be on the full voltage contactor.

b) Should the lead starter be shut down either intentionally or by a fault condition, the dependent starter shall drop out immediately.

c) A time delay shall be incorporated in the interlock circuit to delay the operation of the dependent starter where specified. Such time delays shall be in addition to the interlock circuits.

4.16.19 Auxiliary contacts

Two normally open and two normally closed auxiliary contacts shall be provided for each starter as spares unless otherwise specified. These contacts shall be in addition to contacts used for the control of the starter.

4.16.20 MPCB (MOTOR PROTECTION CIRCUIT BREAKER)

Motor circuit breakers shall comply with the general recommendations of standard IEC 60947-1,-2 and -4-1.

1. The devices will be in utilization category A, conforming to IEC 60947-2 and AC3 conformingto IEC 60947-4-1.
2. Rated operational voltage of 690V AC (50/60 Hz)
3. Rated insulation voltage of 690V AC (50/60 Hz)
4. Isolation conforming to standard IEC 60947-2,
5. Rated impulse withstand voltage (Uimp) of 6 kV.

4.16.20.1 **MPCB shall meet following requirement:-**

4.16.20.1.1 Mounting:

The motor circuit breakers will be designed to be mounted vertically or horizontally without derating Power supply will be from the top or from the bottom.

4.16.20.1.2 Contacts:

In order to ensure maximum safety, the contacts will be isolated from other functions such as the operating mechanism, casing, releases, auxiliaries, etc, by high performance thermoplastic chambers.

4.16.20.1.3 Operating mechanism

The operating mechanism of the motor circuit breakers must have snap action opening and closing with free tripping of the control devices. All the poles will close, open, and trip simultaneously.

4.16.20.1.4 Button:

The motor circuit breakers will be actuated by a rotary operator clearly indicating the position ON (I), OFF (O), trip

4.16.20.1.5 Isolation:

In order to ensure isolation with clearly visible breaking conforming to standard IEC 60947-2 paragraph 7.2.7:

1. The mechanism will be designated so that the different types of operator will only be in position (O) if the main contacts are physically separated,
2. In position (0) the operating devices will indicate the isolated position.
3. Isolation is enhanced by the double break of the main circuit.

4.16.20.1.6 Padlocking

Motor circuit breakers will accept a padlocking device in the "isolated" position.

4.16.20.1.7 Trip

The motor circuit breakers will be equipped with a "PUSH TO TRIP" device on the front enabling the correct operation of the mechanism and poles opening to be checked.

4.16.20.1.8 Limitation, Durability

1. The motor circuit breakers will be current limiting for a mains voltage of 400 V, the maximum let-through energy (IZt) on short circuit being extremely low.
2. The motor circuit breakers will have a high electrical and mechanism durability of at least 5 times that required by the standard.

4.16.20.1.9 Protection functions

General recommendations:

a) The motor circuit breakers will be equipped with releases comprising a thermal element assuring overload protection and a magnetic element for short-circuit protection.

b) In order to ensure safety and avoid unwanted tripping, the magnetic trip threshold (fixed) will be factory set to an average value of 12 Ir.

c) All the elements of the motor circuit breakers will be designated to enable operation at an ambient temperature as per IEC without derating.

d) The thermal trips will be adjustable on the the front by a rotary selector.

e) The adjustment of the protection will be simultaneous for all poles.

4.16.21 **SWITCH FUSE UNITS & DISCONNECTS/ISOLATORS (WHERE APPLICABLE)**

4.16.21.1 Switch fuse units shall have quick-make, quick-break silver plated preferably double break contacts with operating mechanism suitable for rotary operation in the case of cubicle mounting. All switches shall be rated according to the equipment schedule or drawings and shall withstand the system prospective fault current let through. Cam operated rotary switches with adequate terminal adaptors up to 25A are acceptable but for all higher rating switch fuse units shall be heavy-duty type.

4.16.21.2 Fuses shall be HRC cartridge type conforming to IS: 13703 - 1993 with a breaking capacity corresponding to system fault level. Fuses shall be link type with visible indication. Screw type fuses are not acceptable for any ratings.

4.16.21.3 All disconnects shall consist of switch units quick-make, quick-break type with silver plated contacts. The switches shall preferably have double breaks. The switches shall preferably have sheet steel enclosure, which in turn is mounted on suitable angle iron frame work. In wet locations enclosures shall be IP56 rated . Disconnects shall have a minimum breaking capacity of 5KA at 415 Volts.

4.16.21.4 Switch contacts shall be designed with arc repelling features to extinguish the arc quickly to provide long contact life.

4.16.22 ISOLATORS

4.16.22.1 Isolators shall be fixed on wall, on self-supported galvanized angle iron frame work as required and mounted as near to the motor as possible. Where several motors are installed, isolators if required shall be provided at a central location on a common frame work with prior approval at site . The Isolator shall be provided in IP 65 enclosures from the Isolator manufacturer only.

4.16.22.2 Painting, earthing and labels shall be provided as generally indicating for MV Switchgear and as shown on drawings.

4.17 CONTACTORS

4.17.1 Contactors shall comply with IS/IEC 60947-4-1 or EN 60947-4-1.

4.17.2 Contactors shall be electro-magnetically controlled, double air-break type. Contactors shall be four-pole, triple-pole, double-pole or single-pole as shown on the Drawings.

4.17.3 The mechanical endurance of the contactors shall not be less than 3 million no. load operating cycles.

4.17.4 Contactors shall be silver-faced.

4.17.5 The contactor should be modular in design with minimum inventory requirements and built -in mechanically interlocked wherever required. They should be suitable for the addition of auxiliary contacts and other electrical auxiliaries without any compromise on the performance or the operation of the contactors. The contactors from 4KW to 400kW shall be associated with the same 10 auxiliary contact block range or as per BOQ.

4.17.6 The control contactors for power factor correction equipment shall be of quick break and have a high arc resistance during switching operation. Contactors shall be of utilization category AC-6b for this application and specifically designed for switching directly connected capacitor banks.

4.17.7 The contactors for other applications shall have an un-interrupted rated duty and utilization category of at least AC3 at 415V and 50 Hz. The contacts should be of fast opening and fast closing type.

4.17.8 The making and breaking capacity values of the contactors should be as follows (as per IEC 60947-4)

a) For AC3 duty:

- Making capacity equal to or more than 10 Ie
- Braking Capacity equal to or more than 8 Ie,

b) For AC4 duty:

- Making capacity equal to or more than 12 Ie,
- Braking Capacity equal to or more than 10 Ie,

4.17.9 The contactors should be capable of frequent switching and should operate without derating at 60°C for AC3 applications. They should be climate proof. The coil of the contactor should have class H insulation to support frequent switching. Class F insulation is also acceptable with the consent of the site Engineer.

4.17.10 The rated voltage of the contactor and the rated insulation voltage shall be 690V. The rated Impulse voltage of the contactor should be at least 8 KV.

4.17.11 Wherever DC control is required, the contactor should have wide range (0.7 to 1.25 Uc) DC coil with built in interference suppression as required.

4.17.12 The control and power terminals should be at separate layers preferably with colour coding (black for power and white for control). All contactors power connection shall be finger safe (IP 2X)

4.17.13 They should be capable of being integrated into automated system (PLCs) without any interposing components in the minimum operating conditions.

4.17.14 Contactors used with surge suppressor.

4.18 AUXILIARY SWITCHES AND CONTACTS

4.18.1 Auxiliary switches provided for indication, protection, metering, control, interlocking supervisory purposes shall be readily accessible at the front of the Electrical Panels. Adequate secondary contacts shall be included to enable the auxiliary switch to be wired to the fixed portion of the equipment.

4.18.2 For each control compartment, spare auxiliary contacts with a minimum of two NO and two NC contacts shall be provided and wired to suitably identify spare terminals.

4.18.3 Auxiliary contacts for all applications shall be rated at 240 V AC or 110 V DC with contact rating of at least 6 A AC or DC and operating life of atleast one million on on-load operations at 0.4 power factor inductive load.

4.19 POWER FACTOR CORRECTION EQUIPMENT

4.19.1 Power factor correction equipment and its installation shall comply with IEC 60831/IS 13340. Each power factor correction equipment shall consist of capacitors, switchgears, cables, cable gland, micro-processor based intelligent power factor control relays, CTs and contactors etc.

4.19.2 Capacitor banks shall consist capacitors of variable capacity i.e. 5 kVAR, 10 kVAR, 15 kVAR, 25 kVAR or fixed type as per BOQ. Capacitor bank with total capacity as shown on the drawings or BOQ shall be provided and connected to the designated switchgear in the LV main switchboard to improve the overall power factor to not less than 0.98 lagging. The system shall ensure that a leading PF does not occur.

4.19.3 The Contractor shall ensure that the power factor correction equipment shall not cause harmonic resonance in the LV electrical network

4.19.4 The capacitor bank shall be of floor standing type built up from static primary capacitor units. The capacitor shall be mounted on the lower and de-tuned inductor on the upper part of the panel so that the temperature of capacitor environment is lower than the average temperature in the panel. In case, ventilating fan is required to maintain the desired temperature in the capacitor panel, the same shall switch on and off depending upon the set temperature and only when at least one capacitor is in service. The thermostate temperature shall be provided with step adjustment features if considered necessary as per design.

4.19.5 Each three phase capacitor unit shall be MPP self healing type with total losses not greater than 0.5 W/kvar. The primary capacitor unit shall comply with the requirement of IEC 60871-1 or BS 1650.

4.19.6 The capacitor unitshall be usable for indoor application with permissible overloads as below:

- Voltage overloads shall be 10% for continuous operation and 15% for 30 minutes in a 24 hours cycle
- Current overloads shall be 15 % for continuous operations and 50% for six hours in a 24 hours cycle.
- Over load of 35% continuously and 45%for six hours in a 24 hours cycle.

4.19.7 All capacitors involved shall be disconnected instantaneously, and reconnected step by step at intervals after the supply is restored.

4.19.8 Each capacitor bank shall be fitted with an automatic discharge assembly which shall discharge the entire capacitor bank from the peak alternating voltage to a voltage level not exceeding 50 V measured at the capacitor bank terminals one minute after disconnection from the supply.

4.19.9 The automatic power factor control relay (APFCR) shall be a microprocessor based static unit with output relays equal to the no. of capacitor steps. Minimum no. of relays shall be six/eight (6/8) or as specified in BOQ. The switching ON and OFF of the capacitor unit shall be done in a sequence so that even wear takes place on the contactors and relays over one week of operation.

4.19.10 The APFC relay shall be intelligent to ensure balancing of duty cycle of the capacitors. The APFC relay shall be communicable type with RS 485 connectivity.

4.19.11 APFC relays shall provide all necessary function of relay, controls, protection, annunciation and condition monitoring. A no-volt and single phasing protection shall be provided.

4.19.12 Local/off/auto selector switch and visual indication of energized capacitor with red lamps, etc shall be provided.

4.19.13 Type tests for the equipment shall include operating voltage, temperature cycling and repeated switching as per IEC 60831-2

4.19.14 Overcurrent shall be 1.8 x In.

4.19.15 Peak inrush current withstand capacity shall be 250 x In

4.20 DETUNED FILTER

4.20.1 Detuned harmonic filter reactors shall be used as per BOQ along with power capacitors to mitigate harmonics amplification and to avoid electrical resonance in LV electrical networks.

4.20.2 The reactors hall be made of high grade copper windings, having a three phase, iron core construction suitable for indoor use. The reactor are air cooled and the layout shall be in accordance with IEC 60289 / IS 5553.

4.20.3 The permitted tolerance of inductance is ± 3% of rated inductance value.

4.20.4 Reactor tuning factor shall be 7 % (189 Hz) and the current rating of the reactor shall include the effects of harmonics and other possible over-currents

4.20.5 The limit of linearity of inductance of the filter reactor is: 1.8*In with L=0.95*LN.

4.20.6 All reactors shall be fitted with a temperature sensitive micro-switch in the centre coil (normally open) for connection to trip circuits in case of high operating temperatures.

4.21 AUTOMATIC LOAD TRANSFER SWITCHES

4.21.1 Automatic load transfer switches shall be composed of paired ACBs or MCCBs. ACBs and MCCBs used in Automatic Load Transfer switches shall be used as specifiedin this specification.

4.21.2 Paired ACBs or MCCBs (as specified above) shall be provided with motorized mechanisms for "ON/OFF" operation.

4.21.3 Each automatic load transfer switch shall be equipped with, but not be limited to, thefollowing:

a) Illuminated indicator for "Normal Supply On" and "Standby Supply On" to be provided at the front cover of the compartment housing the changeover switches.

b) Transfer mechanism to facilitate automatic/ manual changeover from the normal source to the standby source.

c) Automatic/manual change-over selector switch shall be provided. It shall be possible to manually operate the circuit breakers in the event of absence of control voltage.

d) ALTS should have electrical interlocking along with mechanical interlocking through base plate to ensure that two MCCBs shall not be ON simultaneously.

e) Interlocking facility to insure that normal breaker tripped on fault will not cause standby breaker to close or vice versa, unless the breaker are reset manually.

f) A test switches to simulate mains power failure and indicate the changeover sequence to allow on load testing.

g) Auxiliary relay and contacts to facilate main power source failure for routine testing of the automatic change-over operation.

h) 2 nos. each NO and NC volt free dry contacts shall be provided for each change-over circuit breaker unit.

i) The change-over function shall work without auxiliary power supply with fail safe operation.

j) All indications for all operations viz. ON, OFF, TRIP.

4.21.4 **The changeover system between the normal and standby sources shall be as follows:**

a) 3 phase sensing circuits with adjustable time delay facility in the range of 0 to 15 seconds shall be provided to monitor the voltage condition of the normal and standby source.

b) Failure of one or more phases of normal main supply or are reduction of voltage to a value of 90% to 70% (adjustable) of nominal value shall initiate the timing device. If the failure persist at the expiry of this present time delay, the changeover section will be effected provided that the voltage of the standby source reaches 90% of the nominal value.

c) Upon restoration of the normal power supply, which has been determined stable after a time delay, the changeover switch shall automatically be restored to the normal supply. It shall also be able to switch the load back to the normal supply under manual control.

4.22 DISTRIBUTION BOARDS

4.22.1 Distribution boards for miniature circuit breakers shall be of sheet steel construction with aminimum thickness of 1.6 mm, suitably braced to form a rigid structure. Exterior cornersand edges shall be rounded to give a smooth overall appearance. Hinged swing doors shall be fitted with gaskets and shall be easily removable to simplify installation. DBs shall be provided with suitable size of surge protection. DBs shall be fixed with bottom at 1200 mm from finished floors. DBs shall be fixed properly, fitted square with the frame and with holes correctly positioned. DBs shall be fastened to the walls with suitable grouted studs of not less than 12-mm diameter.

4.22.2 IP ratings for distribution boards shall be IP 54(used for Lights & small power).

4.22.3 All boards shall be meggered phase to phase and to neutral using 1000/500V megger with all switches in closed position. The megger value should not be less than 2.5 M Ohm between phases and 1.5 M Ohm between phase and neutral. Testing of minimum 10 kA short circuit current otherwise specified in BOQ required.

4.22.4 Each distribution board shall be arranged for top and bottom cable entry and shall be provided with ample cable termination plates and chambers to enable cables to be neatly glanded with tails grouped and terminated on to appropriate internal terminations.

4.22.5 Distribution boards shall be wall mounted and shall, where specified, incorporate doublepole or triple pole all insulated switches as appropriate, which shall be front of panel operated with an "ON/OFF" indicator and capable of being padlocked in the "OFF" position. Distribution boards shall incorporate combinations of single pole, double pole, triple pole and four pole miniature circuit-breakers (MCBs/MCCBs) as specified in drawings.

4.22.6 Each bank of MCB’s shall be clearly identified with its appropriate phase colours code, and the mounting framework for the banks of MCB’s shall be easily removable to simplify installation. Adequate phase barriers and shields shall be fitted to ensure that after installation and wiring, all bare terminals and wires are covered to prevent accidental contact with live conductors during the normal procedure of resetting MCB’s.

4.22.7 Each distribution board shall be supplied complete with as built drawing /chart, preferably mounted within the front door. This chart shall be permanently and legibly filled in as circuits are completed, including the circuit description, the MCB rating and theidentification of upstream source of the distribution board.

4.22.8 Each distribution board shall be clearly labeled indicating its service and all 3- phase distribution boards shall be fitted with standard labels as per relevant IS.

4.22.9 In the top and bottom, of each distribution board a 32 mm clear hole in addition to other requirements shall be provided. These spare holes shall be fitted with 32 mm stopping plugs and locknuts.

4.22.10 Spare MCB’s shall be provided on the basis of one per four ways or part thereof for every distribution board ensuring that spares are provided in numbers and rating proportional to the numbers and ratings in the installation or as per BOQ.

4.22.11 Distribution boards shall comply with best industry practice.

4.22.12 All busbars shall be of hard drawn tinned copper having ratings as specified complying to relevant clauses given under clause 4.1 as relevant, and shall be electro-tinned. Neutral busbars shall be of the same cross-sectional area as the phase busbars and shall have adequate number of terminals for all outgoing circuits including spare ways.

4.22.13 The configuration of the busbars, busbar supports and busbar mounting arrangement) shall be rated at 415 V. It shall be certified to a short time withstanding current which is not less than 10 kA for 1 sec at voltage of 415 V as per design.

4.22.14 Multi-terminal connectors shall be provided within the distribution board for connection of protective conductors of all outgoing circuits including spare ways.

4.22.15 Size of the DB shall be optimized precisely by proper utilization of points on MCB. Proper utilization of points reduces the space acquired by DB as well. If the numbers of points are few on MCB then it shall be avoided by adjusting the same on other MCB having sufficient free points. MCB rating shall be as per the number of points to be included. Circuit for areas other than critical rooms e.g. SER, TER, SCR etc. shall be clubbed according to the rating of MCB. While designing DBs, efforts shall be made in such a way that each circuit shall have not more than 800 Watts connected load or more than 10 points, which ever is less. However, In case of LED Points where load per point may be less, number of points may be suitably increased.

5. FINISHES

5.1 Sheet Steel materials used in the construction of these units should have undergone a rigorous rust proofing process comprising of alkaline degreasing, descaling in dilute sulphuric acid and a recognized phosphating process. The steel work shall then receive two dip-coats of oxide filler/primer before final painting. Castings shall be scrupulously cleaned and fettled before receiving a similar oxide primer coat. The manufacturer is required to have 7 tank treatment facility for this.

5.2 All exposed metal surfaces, both internal and external, shall be thoroughly cleaned of all dust, oil, grease, scale, rust or any other contaminants and shall be epoxy powder coated immediately at the manufacturer's factory. In case of any doubt, the painting procedure, paint samples and process shall be approved prior to commencement of painting.

5.3 The epoxy powder coating shall be not less than 50 micron thick and with colour in accordance with BS 381C or BS 4800 as approved by Engineer.

5.4 Every care shall be taken to protect the surface of the panel from damages during transporation and installation. In case, there is any damage, the same shall be made good by the method as approved by the site engineer which may also include change of the panel.

6. NAMEPLATES AND LABELS

6.1 NAMEPLATES

6.1.1 Each Electrical Panels shall have permanently attached to it in a conspicuous position labels upon which shall be engraved or stamped with the manufacturer's name, type and serial number, date of manufacture, designation of each Electrical Panels, details of the loading and duty at which the item of the Electrical Panels has been designed to operate. Such labels shall be of non-hygroscopic material.

6.2 LABELS

1. Labels shall be provided for every panel to describe the duty of or otherwise identify every instrument, relay or item of control equipment mounted externally and internally.

2. The designation on these labels shall be clear and shall, where applicable, incorporate the device number along with concise descriptive wording in English.
3. Externally fitted panel labels shall be of perspex or other approved transparent plastic with letters and numbers rear engraved and filled with black.
4. Internally fitted panel labels shall be finished in white with engraved letters and numbers filled with black, laminated material such as Traffolyte or rear engraved and filled plastic may be used. Embossed materials and techniques will not be accepted or any latest technogoly which provides same result as mentioned above shall be applicable.
5. Labels shall be provided in conformity with the above requirements or by other approved means wherever necessary to designate panels or panel sections. To describe or identify circuits or circuit components, to provide warnings or reminders of dangerous or potentially dangerous circumstances and wherever called for elsewherein this Specification.
6. Safety labels "Danger 415 V in both English and Hindi shall be provided on both the front and rear of the Electrical Panels. The safety labels shall have graphic symbols exactly as per IS standards. The design of all such signs shall be submitted for approval. Similar labels shall be provided for other panels at different voltages.
7. Labels shall not be less than 45 mm high. Lettering shall be of not less than 10 mm high. All labels shall be securely fixed to the panels by bolts and nuts.
8. Details of proposed inscription, including the English and Hindi wordings, and samples of the labels shall be submitted for approval before any labels are manufactured.
9. Circuit labels, one on the front of the panel and one on the rear of the panel suitably engraved.

7. FOUNDATION (IF REQUIRED) AND INSTALLATION

7.1 The location of each foundation shall be correctly set out in accordance with the approved foundation layout drawing. Base channels shall be grouted, leveled in cement concrete pad for switchgear and other cubicle panels, etc. with reference to a bench mark in the building. Pedestal type panels and superstructures shall be erected by grouting foundation bolts into the foundation in cured holes left in foundation blocks. For concreting on existing floors, a proper bonding surface shall be made by chipping the floor. The final finish to the surface of the floor shall be given after all equipment has been installed. If floor is broken for installation of equipment, it shall be restored to original finish after completion of installation.

7.2 The concreting shall be done in accordance with the provision of Indian Standard Code of Practice for Plain and Reinforced Concrete, IS 456-2000. Concreting IS: 383-1970 Specification for coarse and fine aggregates from natural sources for concrete IS: 269-1989 Specification for 33 grade ordinary portland cement IS: 516-1959 Method of test for strength of concrete.

7.3 Suitable grooves or niches shall be provided in the foundation block at the time of casting to enable embodiment of earth strips without calling for chipping of the blocks. Subsequently conduits of appropriate size shall be embedded in the foundation blocks for cabling, in the first instance, wherever required.

7.4 All foundations shall be cast in the presence of the Employer's representatives. All foundation and grouted bolts shall be cured for a minimum period of 48 hrs.

7.5 Foundations shall be prepared as per manufacturers drawing, shall be leveled, checked for accuracy and the switchboards installed. Busbar connections shall be checked with a feeler gauge after installation. Tightness of accessible bolted bus joints shall be checked using calibrated torque wrench. Sealing of cable and boxes to prevent moisture entry shall be checked. Switchboard earth bars shall be connected to the earth grid.

7.6 Fabrication drawings of all panels shall be approved by the Employer's representative before fabrication

7.6.1 The Electrical Panels shall be installed in the locations as approved by the Engineer. Electrical Panels shall be secured, plumbed and levelled and in true alignment with related adjoining work,

7.6.2 The rigid galvanized U-channels to ensure effective fixing of the Electrical Panels on the uneven floor shall be provided.

7.6.3 Anchor bolts and anchorage items shall be provided where required and field checked to ensure proper alignment and location. Templates, layout drawings, and supervision on Site shall be provided to ensure correct placing of anchorage items in concrete.

7.6.4 Supporting members, fastenings, framing hangers, bracing, brackets, straps, bolts, angles, shall be installed as required to set and rigidly connect the work.

7.6.5 Temporary bracing,gauge, or other devices shall be provided as required to accomplish erection and to provide safety and stability until the ELECTRICAL PANELSis in its final and approved position.

7.6.6 Erection tolerance requirements shall be controlled so as not to impair the strength, safety, serviceability, or appearance as Approved.

7.6.7 After installations are complete, all places where the shop applied coating is abraided, all bare steel, including bolts, nuts, washers, and welds shall be thoroughly cleaned. Each item shall be painted with the same paint as used for shop coating in the corresponding location.

8. OTHER PROVISIONS

8.1 The Electrical Panels shall be provided with all necessary cable lugs etc., fixed in positions on mounting plates and straps, to suit the types and directions of entry of the cables as shown on the Drawings or as specified.

8.2 Cable conductors for all circuits within the Electrical Panels shall be arranged in a tidy manner and mechanically secured at regular intervals such that any movement occurring to the conductors, either under normal operation conditions (e.g. thermal expansion, vibration, etc.) or due to short circuit in any one of the circuits, shall not cause any damage or short circuit to any healthy bare live parts in the Electrical Panels.

8.3 Each Electrical Panels shall be supplied complete with all operating handles jigs, etc. required for the normal charging, closing, opening, racking in and out operations of all circuit breakers of the Electrical Panels and shall be properly fixed in a neat manner on a board with brass hooks inside the switch room/plant room where the Electrical Panels is installed.

8.4 Each Electrical Panels shall be provided with two rubber mats of ribbed surface, complying to BS 921 or equivalent Indian standards, laid in front of and at the rear of the switch board. The rubber mats shall be continuous sheets of minimum thickness of 10 mm, each of same length as the switchboard and minimum width of not less than 1000 mm or the width of the space between the fronts or back of the switchboard to the adjacent wall.

8.5 Hydraulic operated handling truck suitable for handling all sizes of air circuit breakers for the Electrical Panels shall be provided as indicated in the BOQ.

9. SPECIAL CONDITION:

9.1 The Switchboard shall be complete with all components and accessories, which are necessary or usual for their efficient performance and satisfactory maintenance under the various operating and atmospheric conditions. Such parts shall be deemed to be included within the scope of supply whether specifically included or not in the specifications or in the tender schedules. The contractor shall not be eligible for any extra charges for such accessories etc.

10. RELIABILITY, MAINTENANCE, SPARES AND LIFE

10.1 The electrical panel shall be designed for reliable and safe working. It shall be designed for a maintenance free secure service life of switchboards, sub-assemblies and components for at least 30 years.

10.2 The manufacturer shall submit the list of spares which are required to be replaced as a must change item along with interval.

11. MATERIAL AND MANUFACTURING:

11.1 All similar items of the Electrical Panels and their component interchangeable. Spare parts shall be manufactured originals and shall fit all similar items of the Electrical Panels. Where machining may be needed before fitting renewable parts, the machining fits and the associated tolerances shall be shown on the drawings accompanying the instruction manuals.

11.2 All parts which are susceptible to wear or contaminated by dust shall enclosed in dust-proof housings.

11.3 The style and finish of the workmanship shall be consistent throughout the Works. Unless otherwise specified, Engineer shall decide the final colours for all paint work and other finishes to be applied to the Electrical Panels.

12. TESTING

12.1 The firm shall submit valid type test not more than 5 years old of the equipment conducted at accredited/authorised/reputed/nominated by DMRC laboratory. The type test shall be as per the governing specification.

12.2 DMRC will carry out Routine and factory acceptance tests as prescribed in the specification with following additional test

12.3 In case of Distribution Boards type test is not essential, however test of short circuit capacity must be submitted.

12.4 The manufacturer shall not change the Bill of Material used in the manufacturing of samples used for Type testing. In case the bill of material is changed then Engineer-in-charge may ask for the repetition of those type test which he considers relevant.

13. TRAINING

The contractor shall provide the following details

Every marshalling box and PLC compartment of the Electrical Panels shall be provided with a wiring diagram suitably treated to prevent deterioration from dirt or age. The diagrams shall be drawn as if viewed from the point of access to the enclosure, and shall be securely fastened to the inside of the access door of that compartment.

- Bound booklet consisting of the details of the equipment
- Operating manual
- Warranty/DLP
- Purchase specification of maintenance spares
- List of staff trained
- Details of service centre

14. INDICATIVE LIST OF ITEMS TO BE INCLUDED IN FAT PLAN FOR ELECTIRCAL PANELS

(This list is an indicative List for the inspectors to be conducted during FAT of Power Panels. However, the detailed FAT plan needs to be developed for the specific Panel based on approved GADs and Contract Specifications and as per the tests defined in Clause – 11 of IEC 61439 -1 (Routine Verification)/as per the relevant Standards as applicable.)			
S. No	**Description**	**Type of Check**	**Remarks**
GENERAL			
A	All items/components (switchgears, cables, wires, meters, relays etc.) used are as per the Approved Makes, Vendors and ratings.	Visual Check & Certification before Call letter	Obtain confirmation from Panel Manufacturer for each Panel duly verified by the Main Contractor.
B	Obtain the Factory Test reports of Incoming/Raw Material	Verify	
C	Obtain the Internal Test reports/Manufacturer Test Report of Internal Quality Tests done on Panel offered for Inspection as per ISO 9001.	Review	
D	Confirmation from Panel Manufacturer that Penel has been manufactured strictly as per approved GADs.	For record	
E	List of tools required for Inspection and copy of their Calibration Certificates from independent Labs/Authorities.	Check for Validity	
Note:	All the above are to be made part of this FAT report		
	Panel must be of Modular construction as per PS. The Inspection team shall carry the approved GAD, approved Bill of materials, Contract Specification, relevant standards, copy of Approvals and approved FAT Plan from the office before proceeding for the FAT inspection to the factory promises.		
Physical/Dimensional Checks(as per approved GADs).			
1	Check the Length, Breadth and Height of the complete Panel.	Measurement	
2	Check dimensions of each Sections and Cubicles.	Measurement	
3	Check Number and dimensions of Space for future additions as per Specifications & Bod.	Measurement	

4	Check dimensions of the Doors/back Panels, etc. (Note: Back Panel sections should not be too bulky to handle by one individual. May be taken care during GAD and checked during FAT).	Measurement	
5	Check height/dimensions of all front Mounting Accessories (such as indicators. Measuring instruments, knobs, etc.)	Measurement	
5.1	EPB (Emergency Push Button) at 1300 mm where applicable.	Measuremnt	
5.2	All Relays & indicating instruments between 300 to 1800 mm	Measurement	
5.3	Max. Operating Height should not be more than 1800 mm	Measurement	
5.4	Blank Space between the Floor of Switch board and bottom unit (Min. 200 mm or as per PS)	Measurement	
6	Check size/height of Base Frame (may be min. 100 mm. or as per PS).	Measurement	
6.1	The make of the manufacturer of bought out items is clearly displayed on the items where possible.		
6.2	Check that all materials used in the manufacturing of the electrical panel are fire refardant, low smoke & zero halogen.		
7	Verify Material and Thickness of Load bearing and Non-Load Bearing Member of Panel Enclosure:	Certificate/Measruement	
7.1	Panel Structure		
7.2	Bus bar Section		
7.3	Cable Alley		
7.4	Switchgear/feeder sections		
7.5	Doors		
7.6	Gland Plate		
8	Check Quality of Sheet Metal Painting and Color used. It should be as per the Specification/Approved drawings.	Visual/Measurement	
9	Check for the Quality of Sheet Metal Workmanship. There shall not be any sharp edges, burrs, dents, etc. on the panel.	Visual	
10	Check Number and Quality of the Door Hinges. Ensure that doors is strongly supported and should not have any unwanted deflection/shakiness. When door is closed, it is latched at adequate places with adequate crushing of gasket on metal frame.	Visual	
11	Check Quality of the Door handles, Locks etc.	Visual	
12	Check interlocking of Doors, Switchgears, incomers, outgoings and couplers as per the design logic and drawing	Verify and Visual Check	
13	Check and compare the sealing arrangements all around the panel to ensure intended ingress Protection is achieved and	Verify and Visual Check	

	compare with the Type test reports.		
13.1	Simple Paper insertion test for IP54. Insert a paper in the gasket and metal frame, close the door and pull the paper. It should nto pull out.		
13.2	Check Quality of Gaskets/sealing rubber, etc. for the Doors. The arrangement shall be such that it is replecable during maintenance.		
13.3	Check Quality of Gaskets/sealing rubber, etc., around the cut-outs for Measuring & indicating instruments, Switchgears, Relays etc.		
13.4	Proper sealing of knock-outs/cut-outs/gaps for control cabling bus bar, etc., between different feeders/sections within the Panels.		
14	Check the Lifting arrangements (Hooks etc.) are provided.	Visual	
14.1	Adequate Number of Lifting points/Hooks		
14.2	Adequate Strength of Lifting Points/Hooks		
15	Check proper identification markings, numbering labeling, tags have been provided.	Visual	
15.1	For the Penel		
15.2	For each incoming and Outgoing Feeders		
15.3	For Measuring and indicating instruments		
15.4	Danger Plates/Signages		
16	Check for rust, any sign of initiation of corrosion, oxidation, etc., on the support members/nut bolts/bus bars/terminal points, etc. Initiation is an indication of use of defective material.	Visual	
CABLE ALLEYS			
17	Check for Cable Entry Arrangement (top entry/Bottom entry) as per GADs.	Visual	
18	Check for Maintenance/Working space in Cable Alleys, etc.	Visual/ Measurement	
19	Check for adequate Space for accommodating Cable Loops, etc.	Visual/ Measurement	
20	Provision for securing/clamping cables in Cable alley for proper dressing of cables.	Visual	
21	Check for Knock outs for Glanding of different smaller sizes of Cables in Marshalling box (to be used for BMS cables).	Visual	
22	Thickness of Glanding Plates should be minimum 5.0 mm & strong enough to take the simultaneous load/forces of cables glanded on to it. The Cables shall be well supported and not exert any force on the glanding plate	Measurement	

23	Proper dressing/harnessing of internal control cables and wiring within the Panel.	Visual	
24	Provision of identification tags/ferrules on the internal control cables and wiring within the Panel.	Visual	
EARTHING ARRANGEMENT			
25	Check that Material of Earth Bus provided in Panel is as per PS.	Visual	
26	Check the Size of continuous Earth Bus provided in the Panel as per IEC.	Measurement	
27	Check if the Earth Bus is properly supported and connected to the outside terminals.	Visual	
28	Check that proper earthing has been provided through out the Panel and all non-current carrying parts are properly earthed.	Visual	
29	All the Gland plates have been earthed properly	Visual	
30	All Doors and openable sections must be earthed through flexible wires/jumpers (dual if required as per Specs)	Visual	
31	Cases of all instruments and apparatus shall be earthed by a conductor of suitable size (but not less than 2.5 sq. mm)	Visual	
32	Check that the Frame of Switchgear is earthed, when racked in to the Cubicie.	Visual	
BUS BAR SECTION			
33	Check Bus bar dimensions as per Approved GAD (Only rectangular Busbar is permitted)	Measurement	
34	Neutral bus shall be of full size	Measurement	
35	Material of the busbar shall be as per approved specification	Visual/ Certificate	
36	Quality (Conductivity) of the Material of the busbar (Copper/Almunium) shall be as per approved specification	Certificate/ Measurement	
37	Check the quality of conducting material used for Bus bar and the Quality of Tinning on the Copper Bus bar.	Certificate/ Measurement/ Visual	
37.1	Factory tinned Bus bars to be used. Obtain the Factory Test certificate and attach the report.		
37.2	Tinning of Bus Bar edges after cutting/sizing also to be checked.		
38	Check that the Bending of Bus Bars should be on Rollers of adequate diameter to avoid undue bending stresses	Confirmation & Cross-Check	
39	Check the fixing/mounting arrangements of Main bus bar to ensure that there are no undue stresses due to misalignment of fixing arrangements. (Focus on the location where Panel is divided in to different sections to ensure that the Bus Bar sections match properly).	Visual	

39.1	Check the proven design of bus bar connections of OEM & its compliance in the manufactured product		
40	Bus bar must be color coded for Phase identification	Visual	
	Note: In case, sleeve is to be provided over the Bus bar for color coding as per PS, then the material of the sleeve must be as per the relevant clauses of PS.		
41	Check the distance between Bus bar supports and compare with Type tested assemblies/Approved GADs.	Measurement	
42	Bus Bar Supports should be of approved material.	Confirmation	
43	Measure minimum Electrical clearences between the bus bars for different Phases, Neutral and Earth. (Main Bus as well as Tap off Bus bars) (Minimum clearance will be between Live parts and Earth)	Measurement	
44	Check the interconnecting / Tap - off links between Main Bus and bus sections for proper tightness etc. (connection with the double split cast brass clamp is permitted)	Measurement	
45	Interconnection between Bus Bar and Switchgear - must be high conductivity Copper Bar and must be insulated and Colour coded	Visual	
46	Proper compartmentation at locations where connecting Links enter the Switchgear section, bus bar sections and Cable Alley must be ensured. (Form - 4 b, Type - 5 to be ensured, for Underground section) For elevated, separate compartments for incoming and Outgoing cable terminations, to be ensured.	Visual	
47	Proper Shrouding of Bus bar joints / tap off points to be ensured. Material to be as per PS of the Contract.	Visual	
48	Proper clearances and seggregation must be maintained between Terminals / Tap - offs of different feeders from Main Bus Bars.	Measurement	
INTERNAL WIRING, TERMINAL BLOCK			
49	Check if the Wiring for all power and Control circuit is being provided as per Approved GAD / Specifications.	Verify Material Test Certificate	
	Note:- Internal Wiring in LT panels to be LSZH / FS as per Specs for Underground stations. For elevated stations, internal wiring may be ensured as per PS.		
50	Termination arrangements		
50.1	Terminal blocks should be of Non - Hygroscopic of Melamine	Verify Material	

50.2	At terminal points - Plain and Spring Washers with electro - tinning to be used	Visual	
50.3	Check the tightness of wiring termination	Visual	
50.4	Terminal should have test probe facility	Visual	
50.5	All Live parts of Terminal blocks must be fully shrouded	Visual	
50.6	Spare Capacity of Terminals	Visual	
50.7	Cable terminations should be with lugs of adequate size and with proper crimping	Visual	
50.8	No more than two wire to be connected to the Terminal	Visual	
50.9	Terminals should have identification Labels.	Visual	
50.1	All cables should have identification ferrules	Visual	
50.11	Check if the adequate size of the cables / wires is being used for the control wiring	Measurement	
50.11	All the internal wiring shall be properly dressed and randomly check the tracebility of the wires from the wiring diagram	Visual	
50.12	Check Provision of Protection for Control wiring as approved	Visual	
MARSHALLING BOX for BMS (if applicable)			
51.1	Marshalling Box / Separate chamber for the BMS connection is provided as per the Approved GAD	Visual	
51.2	Check the BMS points have been provided as per the approved I/O schedule	Visual	
51.3	Provision of Softlinks points for the control shall be checked	Visual	
51.4	All the terminals for the BMS shall be properly secured and identification mark along with the voltage level shall be provided	Visual	
51.5	Randomly check voltage level at the BMS points for any leakage voltage etc (at Potential free contacts)	Measurement	
51.6	No power wiring / cable should pass through marshelling box	Visual	
SWITICHGEARS, PROTECTIONS, INDICATIONS, ANNUNICATIONS AND MEASURING INSTRUMENTS			
52	Detailed Check list for these items of the Panel may be prepared based on the GADs / Contract Specifications	Factory Test Certificates and Test during FAT	
53	Test Certificates / Calibration Certificates for Measuring instruments to be ensured	Factory Test Certificates	
54	Check Surge Arresters (if applicable) have been provided	Visual & Manufacturer’s Test Reports	
55	Separate CTs for Measurement and Protection of relevant Class and Burden as per PS to be ensured	Visual & Manufacturer’s Test Reports	

56	Check Control Logics, Interlocks and Protections Schemes in detail as per the approved plan / arrangement.	Visual, Simulation, Primary & Secondary Injection etc	
57	Check the working of ALTS & Controls provided for safe operation.	Visual, Simulation, Primary & Secondary Injection etc	
	MISCELLANEOUS		
58	Check the lights, sockets, anti condensation heaters and air circulation means provided in the Panels as per GADs.	Visual	
59	All the Control and power wiring must per properly segregated.	Visual	
60	Padlocks and interlock provision and Functions to be checked for the safety for each.	Visual	
61	Check for extendability of the Panels (including Bus Bars) on either side.	Visual	
62	Check provision of entry for Fire Trace Tube and internally with in the various cubicles and adequate sealing arrangements.		
63	Ensure that there are No Joints in the cables used		
64	The tests defined in Clause - 11 of IEC 61439 - 1 (Routine Verification)/as per the relevant Standards as applicable are also to be performed for which separate Test sheet may be prepared.		
65	The make of the manufacturers of bought out items is clearly displayed on the items where posible.		
66	Check that all materials used in the manufacturing of the electrical panel are fire refardant, low smoke & zero halogen.		
APFC PANEL			
67	Ensure that material/equipment of only one make is used in the entire Electrical Panel assembly.		
68	Check the make, rating and specification of capacitors used.		
69	Check the functioning of APFEC relay as defined in the operating manual of the relay.		
70	Check the installation of capacitor & inductor as per the form & specification.		
71	Check the working of cooling fans only when temperature goes above set value and atleast one capacitor in service.		

72	Check the sizing of the filter used to ascertain the cleaning frequency for continuous working of cooling fan.		

15. DATA SHEET -

S. No.	Description	Unit	Values		
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					
26					
27					
28					
29					

Length marking: Length shall be marked with number at one meter intervals on the sheath.

*Bidder to furnish the data

A16: LV Power and Control Cables

TABLE OF CONTENTS

A16.0 LV Power and Control Cables

A16.1 General

A16.1.1 This Section specifies the manufacture and installation of Power and Control Cables.

A16.2 Standards

A16.2.1 **Relevant Codes and Standards**

A16.2.1.1 The power / control cables shall comply with the latest versions of the relevant requirements of the British Standards, International Electromechanical Commission (IEC) standards, European and other International Standards specified in this section of Specifications or approved equivalent International standards.

The following standards for cables and cable testing shall apply where appropriate:

Electric cables. Thermosetting insulated, armoured cables for voltages of 600/1000 V and 1900/3300 V, having low emission of smoke and corrosive gases when affected by fire	LSZH	BS 6724
Electric cables. Thermosetting insulated and thermoplastic sheathed cables for voltages up to and including 450/750 V for electric power and lighting and having low emission of smoke and corrosive gases when affected by fire	LSZH (Non-armoured)	BS 7211
Specification for 600 / 1000V fire resistant armoured cables having thermosetting insulation and low emission of smoke and corrosive gases when affected by fire	FS cables	BS 7846
Specification for insulating and sheathing materials for cables. General introduction.		BS 7655-1-3
Specification for conductors in insulated cables and cords	IEC 60228	BS EN 60228
Test method for resistance to fire of cables required to maintain circuit integrity under fire conditions		BS 6387
Tests for electric cables under fire conditions		**BS 6387:2013**
Method of determination of amount of Halogen acid gas evolved during combustion	IEC 60754 – Part 1 and 2	BS – EN - 60754 Part 1 and 2
Determination of flammability by	ISO 4589-2	ASTM – D2863

oxygen index		
Method for determination of temperature index	ISO 4589-3	ASTM – D2863
Measurement of smoke density of electric cables burning	IEC 61034	
Methods of test for insulation and sheaths of electric cables	IEC 60811	**BS 50396/ BS EN 60811**
Calculation of continuous current rating of cables	IEC 60287	
Specification for performance of mechanical and compression joints in electric cable and wire connecting		BS EN 61238
Mechanical cable glands		BS 6121
Requirements for electrical installations IEE wiring regulations. Sixteenth edition		BS 7671
Measurement of smoke density of electric cables burning under defined conditions	BS 7622 Parts 1, 2	BS EN 50268 - 2
Test on gases evolved during combustion of materials from cables. Determination of the halogen acid gas content	IEC 60754	BS EN 60754-1:2014

(Note: In case of contradiction between various standards mentioned, the latest and most stringent standard will apply)

A16.3 Technical and Installation Requirements

A16.3.1 Quality Control

A16.3.1.1 Cables shall be manufactured from fire resistant/retardant, low smoke and halogen free materials, and utilised at locations as specified herein.

A16.3.1.2 All the cable requirements listed herein shall be met without compromising the mechanical and electrical properties of the cables both during and after installation.

A16.3.1.3 The Employer's Representative / Engineer shall have such access to the premises of the Contractor / Manufacturer as is reasonable to enable him to determine the quality of the material and the workmanship and may reject any part of the cable which may appear defective either in material or workmanship.

A16.3.1.4 For Underground areas such as tunnels and stations, the cables shall be XLPEinsulated (except for cables as per BS7211 (table 3), which shall be with EL-5 / GP-6 insulation for applications listed in Table A1, Annexure A to BS7211) with LSZH properties as described in clause A16.3.2. Further, these cables should have reduced flame propogation properties to BS EN50268/61034.

A16.3.1.5 Cables used in external or open areas shall be ultra violet radiation stabilised.

A16.3.1.6 Employer's Representative / Engineer may direct contractor / manufacturer to conduct tests listed in clause A16.3.9 and A16.2.1.1. This shall not preclude any further tests, which may be required to determine the quality of the cable. If so desired by the Employer's Representative / Engineer, the tests shall be conducted at a recognised testing laboratory.

A16.3.1.7 Unless otherwise specified, all power and auxiliary / control cables shall be rated at 600 / 1000 V for armoured and non-armoured cables and 450/750 V for non-armoured wires.

A16.3.2 Construction Requirement for cables required for Underground Station

A16.3.2.1 Power and Auxiliary Cables for use in the Underground areas of DMRC Metro shall be of the type and manufactured to the standards as given below.

(a) Cables conforming to BS 7846: "Specification for 600 / 1000V fire resistant armoured cables having thermosetting insulation and low emission of smoke and corrosive gases when affected by fire"

Fire resistant / fire survival power cables shall be provided for the emergency lighting circuits, UPS supply circuits, battery and charger circuits, fire services installations, smoke extraction system, staircase pressurization system, fireman lifts, disable lifts, and those circuits required to maintain circuit integrity under fire conditions. Cables for loads classified as the "Emergency" loads shall be Fire Survival type and shall conform to NFPA requirements.

(b) Cables conforming to BS 6724: "Specification for 600 / 1000V armoured electric cables having thermosetting insulation and low emission of smoke and corrosive gases when affected by fire "

(C) Cables conforming to BS 7211. "Specification for Thermosetting insulated cables (Non-armoured) for electrical power and lighting with low emission of smoke and corrosive cases when effected by fire ". In case of FS wires, it must also comply with CWZ category of BS6387.

Other than the cables specified in Clause A16.3.2.1 (a), cables for Essential and Non-essential circuits shall be of the type specified in Clause A16.3.2.1 (b) and (c).

Some of the major constructional features of these cables are described below. Further requirements additional to the standards mentioned are also described and the same must be complied with. In case of any contradiction between these the most stringent conditions will apply.

Conductors

a)The conductors shall be of stranded, high conductivity annealed copper wire complying with all the requirements of IEC 60228 and **BSEN 60228**.

b) Cables for fixed installations shall have conductors with stranding to Table II Class 2 of IEC 60228 or BS EN 60228, and flexible cables shall have stranded conductors to Table II Class 5 of IEC 60228 or BS EN 60228.

c) Conductors shall be smooth, uniform in quality, free from scale, spills, splits and any other defects. There shall be no joints in individual strands except those made in the base rod or wire before final drawing.

A16.3.2.2 Insulation

All cables shall be insulated with extruded Cross-linked Polyethylene (XLPE) / complying with the requirements of BS 7655-1.3 (Type GP8). However, whereever the cables as per BS7211 are required, type of insulation shall be used for installation in surface mounted or embedded conduits or similar closed systems. The insulation properties and construction shall comply with the relevant clauses of BS 6724 / BS 7211 / BS 7846 for different types of cables mentioned in Clause A16.3.2.1 of this Specifications. The multicore XLPE insulated cables shall be rated for continuous operation at a maximum conductor temperature of 90 ºC and for a maximum short circuit temperature of 250 ºC.

A16.3.2.3 Cable and Wire Colours

a) All single-phase wires and cables shall be colour coded, i.e. Red, Blue and Yellow colours.

b) Black denotes the neutral conductor and other colours denote the phase conductors.

c) The earth conductor shall be coloured green.

A16.3.2.4 Fillers and Binders

a) Low Smoke and Zero Halogen Fillers and synthetic binders, compliant with the relevant clauses of BS 6724 / BS 7211 / BS 7846 for different types of cables mentioned in Clause A16.3.2.1 of this Specifications, shall be applied to ensure that the cable is compact and reasonably circular, If necessary

A16.3.2.5 Bedding

b) The bedding shall consist of an extruded layer of low smoke halogen free bedding compound compliant with the relevant clauses of BS 6724 / BS 7211 / BS 7846 for different types of cables mentioned in Clause A16.3.2.1 of this Specifications.

A16.3.2.6 Armour

a) Armouring shall be of galvanised steel wire compliant with the relevant clauses of BS 6724 / BS 7211 / BS 7846 for different types of cables mentioned in Clause A16.3.2.1 of this Specifications. The direction of lay of the armour shall be left hand, and the wire shall be sized in accordance with the manufacturer’s recommendations.

b) Where single core cables are armoured and are in use on ac circuits, the armouring shall consist of non-magnetic material.

A16.3.2.7 Over-sheath

a)The over-sheath of the cable shall be an extruded layer of anti-corrosion, reduced flame propagation, low smoke halogen free compound complying with the relevant clauses of BS 6724 / BS 7211 / BS 7846 for different types of cables mentioned in Clause A16.3.2.1 of this Specifications and the fire performance requirements in clause A16.3.3 of this M&W Specification.

b) The colour of the over-sheath shall be black as required.

c) Outer sheath should be of such material to make the cable rodent and termite proof.

A16.3.2.8 Properties of Cable Sheathing

a)Physical properties of the cable sheathing materials shall comply with the relevant clauses of BS 6724 / BS 7211 / BS 7846 for different types of cables mentioned in Clause A16.3.2.1 of this Specifications and have the following requirements when tested in accordance with **BS EN 60811**.

Property	Requirement
Minimum tear resistance	8 Nmm-1

A16.3.2.9 a) Cables to be used should be moisture – resistant and to be tested through gravimetric water penetration test.

b) Cables used in moist area should be corrosion resistant.

A16.3.3 Fire Performance Requirements

A16.3.3.1 **Flammability**

a) The bedding and over-sheath of the cable shall have a minimum oxygen index of 30 when tested in accordance with ISO 4589 – 2 / ASTM – D2863

b) The temperature index of the bedding and over-sheath of the cable shall not be less than 280 °C when tested in accordance with EN ISO 4589-3 / ASTM – D2863.

A16.3.4 Flame Propagation/Integrity under fire conditions

A16.3.4.1 **Fire Resistant or Fire Survival Cable**

Fire Resistant / Survival cables shall comply with the requirements of BS 7846 .

A16.3.4.2 **XLPE Insulated LSZH cables as per Clause A16.3.2.1 (b) and (c)**

a) These cables shall comply with the requirements of BS EN **60332**/BS EN 50268/**61034** / IEC 60332: Part 1 for tests on a single cable under fire conditions when tested in accordance with that standard.

b) The cables shall comply with the requirements of BS EN **60332**/**61034** /IEC 60332: Part 3 Category 'A' for tests on bunched cables under fire conditions when tested in accordance with that standard.

A16.3.5 Corrosive and Acid Gas Emission

A16.3.5.1 The level of hydrochloric acid gas (HCl) emission of the insulation, fillers, binder tapes, bedding, and over-sheath of the cable shall not be greater than 0.5% when tested in accordance with IEC 60754 / BS EN 60754 Part 1 , whichever is latest.

A16.3.6 Smoke Emission

A16.3.6.1 The value of smoke generated (Ao) shall meet the requirements of the relevant clauses of BS 6724 / BS 7211 / BS 7846 for different types of cables mentioned in Clause A16.3.2.1 of this Specifications, when a sample of the complete cable is tested in accordance with IEC 61034 / BS 7622 /**BS 61034** (3 m Cube Test).

A16.3.7 Toxic Gas Emission – Not used

A16.3.8 Cable Current Carrying Capacity and Design Parameters

A16.3.8.1 The maximum continuous current carrying capacity and the factors for determining such ratings and temperatures, for XLPE insulated cables shall be based on IEC 60287 and on the conditions available at Site.

A16.3.8.2 The maximum continuous rating of the cable shall be based on the following conditions:

a) Cables laid direct in ground or buried pipes

Ground or duct temperature -50 °C

Depth of laying to top of cable – as actual

b) Cables in air in railway tunnels:

Ambient air temperature - 50 °C

c) Cables in air above ground:

Ambient air temperature (shade) - 50 °C

d) Maximum continuous conductor temperature:

XLPE insulated cables (up to 1000 V) - 90 °C

e) Rated duration for maximum short circuit current: - 3 sec

f) Max temperature under Short circuit conditions: - 250 °C

A16.3.9 Testing of Cables and Accessories

All the materials employed in the manufacture of the cable shall be subjected to tests specified in relevant standards before manufacture of the cable.

The manufacturer must have type test certificates from the third party accredited laboratories certifying compliance to all the type tests mentioned in the relevant clauses of BS 6724 / BS 7211 / BS 7846 and relevant tests mentioned in Clause A16.2.1.1. In case of non – availability of these test certificates, the manufacturer must get these cables type tested at third party accredited laboratory prior to production of cables. The sample selection for the all type tests shall be as per Annexure P.2 of BS 6724 & BS 7846 respectively. The type test report shall consists of all the tests confirming to table-2 of BS 6724 & BS 7846 respectively.

After completion of manufacture and prior to dispatch the cables shall be subjected to routine & acceptance tests as specified in relevant standards.

Any additional test during work execution required by the employer shall be at employer's cost.

A16.3.10 Cable Construction Identification

A16.3.10.1 The individual cores of the cable shall be clearly identifiable in terms of phase sequence.

A16.3.10.2 The over-sheath of the cable shall be embossed with the following legend:

Voltage Designation	Cable Marking
240/415 Volts	'Electric Cable 600/1000 V' or
	'Electric Cable 450/750 V'

A16.3.10.3 A means of identifying the manufacturer, year of manufacture, conductor size and insulation type shall be provided throughout the length of the cable. If the identification is by means of embossing, it shall not affect the spacing of the legend specified above. If the proposed power and control cables are approved by any product certification agency like BASEC, LPCB etc., the agency trade mark/name shall be present on the embossing of cables.

A16.3.10.4 All FS cables shall have continuous red strip throughout the cable length for the ease of identification.

A16.3.11 Cable Drums

A16.3.11.1 Immediately after the manufacturer's tests both ends of every length of cable shall be sealed by enclosing them with Approved caps, tight fitting and adequately secured to prevent ingress of moisture.

A16.3.11.2 The ends of the factory lengths of cable shall be marked "A" and "Z", "A" being the end at which the sequence of core numbers is clockwise and "Z" the end at which the sequence is anti-clockwise.

A16.3.11.3 The end which is left projecting from the drum shall be consistently "A" or "Z", and shall be protected against damage in such a manner that the enclosure cannot be easily removed during handling while in transit

A16.3.11.4 Cable drums shall be stored on well-drained hard surfaces to prevent cable drums sinking and to simplify drum movements.

Cable drums shall be stored on battens placed directly under the flanges. Storage shall be in such a manner to leave sufficient space for air circulation. Every three months of storage the drums shall be rotated 90^o in the direction of the arrow.

During storage the ends of the cable shall remain properly sealed to prevent ingress of moisture.

Adequate shelter from rain and sun shall be provided. Adequate drainage shall be provided to prevent the cable drums standing in water.

Cable drums shall not be dropped during transit, and cranes should be employed during unloading. Cable drums should be rolled only in the direction of the arrow.

If passing one cable to another drum, the cable drum sizes must be the same.

During removal of the cable from the drum the minimum bending angle of 1 in 15 shall not be exceeded.

Pulling force when using stockings shall not exceed 9D in Newton (N) where D is the outer diameter of the cable.

Drum Lengths

Cables shall be supplied in drum lengths as follows:

- Medium voltage power cables up to and including 6 sq. mm - 1000 m.
- Medium voltage power cables from 10 sq. mm up to and including 400 sq. mm - 500 m
- Control cables - 1000 m

A tolerance of + 5% shall be permissible for each drum.

5% of the order quantity can be supplied in non-standard lengths of not less than 100 metres.

A16.3.11.5 **Packing and Marking**

Packing

Cables shall be dispatched in wooden / metallic drums of suitable barrel diameter, securely battened, with the take off end fully protected against mechanically damage. The wood used for construction of the drum shall be properly seasoned, sound and free from defects. Wood preservatives shall be applied to the entire drum.

Marking

On flange of the drum, necessary information such as manufacturer's name, type, size, number of cores, voltage grade of cable, length of cable in metres, drum No, cable code, finish, gross and net weights etc. shall be printed. An arrow shall be printed on the drum indicating the direction of rotation of the drum.

A16.3.11.6 All cable drums shall be arranged to take a 100 mm diameter round spindle and shall be lagged with strong closely fitting battens so as to prevent damage to the cable. Each drum shall bear a distinguishing number, either printed or neatly chiselled on the outside of one flange.

A suitable spindle shall be provided with each consignment for loading and unloading where the gross weight of the drum and cable exceeds 10 tonnes.

A16.3.11.7 The words "Running End A" or "Running End Z" as appropriate shall be marked on the flange.

A16.3.11.8 All cables and accessories shall be carefully packed for transport and storage on Site in such a manner that they are protected against all climatic conditions, particular attention being paid to the possibility of deterioration during transport to the site by sea or over-land and to the conditions prevailing on the Site.

A16.3.11.9 Wooden cable drums shall be suitably constructed to avoid any problem due to shrinkage. The drums shall be designed for use in conjunction with any special cable-laying equipment complete with spindles and cable drum braking gear.

A16.3.12 Cable Installation

A16.3.12.1 This clause covers the requirements for the use and installation of all cables on or in conduits, trays, trunking and accessories.

A16.3.12.2 All cables shall be provided with identification labels at each end and at each position where cables change direction. In the instances where cables are multiple runs, labels shall be provided at 10 m intervals indicating run number also. Identification discs for cables installed within buildings or tunnels shall be supplied and attached with galvanised wire to each cable at intervals not greater than 12 metres and at all cable terminations.

A16.3.12.3 Cables shall be installed in accordance with this M&W Specification and BS 7671 and shall be run between their source and termination points on or in cable ladder/trays, ducts, cable brackets, trunking and conduits.

A16.3.12.4 Cables running horizontally at high level shall in general be supported by cable ladder and/or perforated cable trays or trunking. Where cables are installed in vertical ducts or on vertical cable ladder/tray, they shall be cleated at intervals not exceeding 1,200 mm

A16.3.12.5 Where cables pass through fire-rated walls and floors, all openings shall be sealed with fire-resistant material of a fire rating equivalent to that of the fire rating of the wall or floor approved by Jaipur Fire Services.

A16.3.12.6 Where cables are to be laid at ground level these may be laid in concrete duct banks (with or without conduits) or laid in GI / HDPE / RCC pipes available directly in ground as per the approval of Employer's Representative. The cables shall be segregated according to their duty.

A16.3.12.7 Cables shall be installed with a minimum of 300-mm clearance from any equipment or pipe work including lagging associated with other services. Where this condition is unavoidable or difficult to maintain, the Employer's Representative shall be informed prior to the installation being commenced.

A16.3.12.8 The power cables shall, for interference purposes be separated from the signal & communication cables in the tunnel, stations & under platform voids. Control and other cables shall be routed separately from traction or power cables. Cables shall be installed so that any one cable can be removed without disturbance to cables from other circuits in the same route.

A16.3.12.9 Materials manufactured for use as conduits, raceways, ducts and their surface finish materials, when installed in stations and train-ways shall be capable of being subjected to temperatures up to 930^{o} F (500^{o} C.) for an hour, and shall conform to the National Electrical Code (NFPA 70). They shall also conform to the codes of the National Electrical Manufacturers Association (NEMA), the American National Standards Institute (ANSI), and Underwriters Laboratories, Inc.

Materials manufactured for use as conduits, raceways, ducts and their surface, finish materials when used for emergency power circuits shall be strong and durable.

A16.3.12.10 All cable routes near tracks are to be parallel or perpendicular to the running lines.

A16.3.12.11 In general two cable routes shall be constructed, one each for Up and Down lines, with minimum changes of directions. Bends shall not be less than the manufacturer's recommended minimum bending radius for the cables to be installed.

A16.3.12.12 Cables passing under road and railways shall be mechanically protected (i.e. HDPE / Galvanized iron sleeves / pipes) and have a minimum cover of 1000 mm. Proper care must be taken for jointing of metallic pipes, so that they do not give way due to weight above and damage the cables.

A16.3.12.13 Track crossings are to be at right angles and at least 2 m clear of any rail switches or crossing areas of leads.

A16.3.12.14 All cable entries into cable pit shall have rounded edges to prevent damage to cables during installation or during service or as a result of the weight of the cables themselves bearing against the edges.

A16.3.12.15 Unarmoured cables, which are direct buried, shall be mechanically protected throughout their length such as laid in metallic pipes or by other equivalent methods.

A16.3.12.16 Cable route markers shall be installed for underground cables where cables change direction and on straight runs of cable at intervals of no more than 50 m. Markers shall be of pre-cast concrete type and be marked "electrical cable" and have a projection of 200 mm above the finished ground level.

A16.3.12.17 Cables shall be installed without tee joints.

A16.3.12.18 Cable armour shall be earthed at one end or both ends of the cable as required by the installation and system. Cleats shall be of the moulded reinforced nylon type of low smoke and halogen free materials.

A16.3.12.19 Where cables are laid in concrete troughs, the trough opening shall be sealed with concrete slabs.

A16.3.12.20 Bends in cables shall have an internal radius of not less than six times the overall cable diameter, or as specified by the cable manufacturer.

A16.3.12.21 Where cables are laid in open ground they shall be bedded in 75 mm of sieved sand, covered with a similar material, and protected by concrete slabs or interlocking tiles, and the trench shall then be back filled. Medium voltage and signalling cables shall have a minimum cover of 750 mm.

A16.3.13 Not Used.

A16.3.14 Installation of Insulated Power Cables

A16.3.14.1 The installation and handling of cables shall be undertaken at all times by adequate and suitably trained staff, equipped with all the necessary plant, equipment, tools and lighting.

A16.3.14.2 Every precaution shall be taken to ensure that the cables and accessories are not installed in a manner or under conditions likely to cause electrolytic or other corrosive action or damage to the cables, or be detrimental to the performance of the cable during operation.

A16.3.14.3 The cable system shall be fully protected from mechanical damage and be accessible at all points for inspection.

A16.3.14.4 All cables installed shall conform to the relevant International standard for acceptable bending radius.

A16.3.14.5 In case, it is unavoidable, to cut any cables during installation, all cut ends shall be properly sealed.

A16.3.14.6 All transitions where cables pass from one graded area to another shall have an approved means of sealing the aperture against fire transference.

A16.3.14.7 The maximum pulling force on any cable shall not exceed the design force of the cable.

A16.3.14.8 All bolts, studs and nuts supplied shall comply with the relevant requirements.

A16.3.14.9 All exposed metalwork surfaces shall be properly painted, finished and galvanised as per relevant specifications.

A16.3.15 Installation of Cable Supports for Insulated Power Cables.

A16.3.15.1 The design of all support and fixing items shall ensure freedom from rough edges, burrs and sharp corners. No materials shall be used which will promote electrolytic or other corrosive action in contact either between the various parts, or with the cable sheaths or the building surfaces and other materials with which they may make contact. All cable supports shall be hot dipped galvanised.

A16.3.15.2 Hot dipped galvanised cable supports that are subject to excessive humidity shall be protected with an approved coating.

A16.3.15.3 The cable supports required for the installation of single-core cables forming three phase circuits shall permit the cables to be laid in close trefoil formation in case of three-phase circuit without neutral conductor or quadrature formation in case of three-phase circuit with neutral conductor. Non-magnetic metal cleats shall be used for this purpose. Low smoke halogen free packing material shall be applied between the cables and the cleats to avoid damaging the cable sheath by the installation of the cleats.

A16.3.15.4 Where single core cables in trefoil or quadrature formation are secured in cleats, intermediate binders of approved material and construction shall also be fitted around the formation to prevent the cables separating under fault conditions. The binders shall be secured around the cables by means of a bolted connection with low smoke halogen free packing material applied between the cable and the binder.

A16.3.15.5 Unless otherwise indicated on the Drawings, all non-armoured cables, where required to be run on walls, ceilings or other building structures, shall be secured or enclosed in conduit or trunking. Armoured cables shall generally be supported by cable ladders, cable trays or cable brackets.

A16.3.15.6 Every cable, whether in or out of sight, shall be neatly run vertically, horizontally or parallel to adjacent walls, beams or other structural members.

A16.3.15.7 Spacing of clips, saddles and cleats shall be such as to prevent sagging of the cables at all times during their installed life.

A16.3.15.8 All steel trays, supporting steel work, brackets, clamps, hangers, cleats, saddles and other fixings necessary for the support of the cables shall be approved by the Engineer, and be of adequate strength for the cables they are supporting. All supporting steelwork and brackets shall be fitted with adjustable mechanisms.

A16.3.15.9 Where a number of cables are terminated to any particular item of plant or machinery, special care shall be taken to ensure that the cables finally approach the plant or machinery from a common direction and are individually terminated in an orderly and symmetrical fashion.

A16.3.15.10 At joints and terminations, all cables shall be adequately supported and secured by cable cleats at a distance of not more than 300mm from the glands or joints.

A16.3.15.11 LV power cables terminated onto the LV cable box of the Distribution transformer shall not impose load on the LV cable box to cause sagging, distortion, etc.

A16.3.16 Termination

A16.3.16.1 The terminating kits shall be suitable for termination of the cables on an indoor switchgear or equipment. These shall be of proven design and shall be type-tested as per relevant Indian or International Standards. Type test certificates shall be submitted. The cable and wire terminations shall avoid any possibility of loose joint and wire snapping. Cable conductor termination shall be by means of a heavy-duty solder less cable lug. The lug shall be of high conductivity copper, electro-tinned and applied to the conductor by means of a hydraulic crimping tool. All such crimping should meet the requirements of BS 4579/**BS61238**.

A16.3.16.2 The cable sheath shall be clasped by means of a gland of compression type based on BS 6121 or equivalent Indian standard with a compression washer, which will hold the cable sheath securely. A cable shroud shall be fitted to cover the body of the compression gland.

A16.3.16.3 All wires shall be terminated with an Approved type of connector.

A16.3.17 Cable Glands and Accessories

A16.3.17.1 Non-Armoured Cables

a) All cable glands and accessories shall be to BS 6121 or equivalent Indian standard.

b) The cable glands shall have a watertight seal when fitted to a cable.

c) Each cable gland shall be supplied with a brass gland locknut and a flame retardant low smoke halogen free outer gland shroud. The shroud shall totally enclose the gland body and form an effective seal against the cable sheathing.

A16.3.17.2 **Armoured Cables**

a) All cable glands and accessories shall be approved to BS 6121 or equivalent Indian standard.

b) The cable glands shall have a watertight seal when fitted to a cable.

c) Cables shall be terminated in a gland fitted with an armour clamp and an earth tag. The gland body shall be provided with an internal conical seal to receive the armour clamping cone, and a clamp nut, which shall secure the armour-clamping cone, and conical armour seal. The spigot of the gland body shall be threaded to suit standard conduit accessories. A flame retardant low smoke halogen free shroud shall be fitted to cover the gland body.

A16.3.17.3 **Cable Ties**

a) Cable ties shall be made from corrosion resistant, flame retardant and ultra violet stabilised materials. At locations where cables are installed above tracks or in areas subjected to significant and constant vibration, cable ties shall be of metal construction type and coated with a corrosion resistant, low smoke halogen free and flame retardant insulation material.

A16.3.18 Cable Joints

A16.3.18.1 The straight through jointing kits shall be suitable not only for conditions of high humidity encountered in Metro sub-way, but also for underground buried installation with uncontrolled back-fill and possibility of flooding by water. These shall be of proven design and shall be type-tested as per relevant Indian or International standards. Type test certificates shall be submitted.

The jointing kits shall match the cable specifications. Joints shall not be permitted in the fire survival cables in case the joint does not meet the fire survival conditions.

A16.3.18.2 Every connection at a cable joint shall be mechanically and electrically sound, be protected against mechanical damage and any vibration, shall not impose mechanical stress on the fixings of the connection and shall not cause any mechanical damage to the cable conductor.

A16.3.18.3 The appropriate tools specified by the joint manufacturer shall be used when jointing cables.

A16.3.18.4 The outer casing/outer sheath of the cable joint shall be fabricated from a low smoke halogen free material.

A16.3.18.5 No cable joints shall be allowed without the prior Approval of the Employers Representative / Engineer. All joints, accessories and cable joint locations shall be submitted to the Engineer for Approval prior to any jointing of cables. All cable jointing shall be performed by a qualified jointer and preferably by the manufacturer of the jointing kits.

A16.3.19 Cable Identification

A16.3.19.1 All cables shall be provided with identification markers, at each end of the cable, at entry and exit point of cable trays, ducts and trenches and in other such positions as are necessary to identify and trace the route of the cable. Identification discs for cables installed within buildings or tunnels shall be supplied and attached with galvanised wire to each cable at intervals not greater than 12 metres and at all cable terminations.

A16.3.19.2 Cable identification shall be assembled from elliptical profiled low smoke halogen free markers, carrier strip and cable ties.

A16.3.19.3 Every single core cable and every core of a multi-core cable shall be provided with identification at its terminations in the form of sleeves or ferrules of appropriate colours or as specified for signalling cables.

A16.3.20 **Screened Signal and Control Cables**

A16.3.20.1 **General**

a) The control cables shall meet the requirement specified in this Section.

b) Cables for protection and control functions associated with the Power Supply System and Fire Alarm System, and used on line-side routes, shall be armoured and shall be low-smoke, non-halogenated type where used on underground sections or in enclosed public areas. All critical control cables shall be duplicated and run separately in the underground section. SCADA related wiring shall be terminated in supervisory termination cabinets.

c) The control cable shall be heavy-duty type, 600V / 1000 V grade FRLS (complying with the standards BS 6724 and BS 7846, as specified above for Power and Auxiliary cables and fire performance requirements specified in Clause A16.3.3 of this M&W Specification.), nil halogen with stranded copper conductor of suitable size. The outer sheath shall also be mixed with chemicals for protection against rodent and termite attack. Wherever specified, fire resistant type cable shall be provided.

d) All cables for fire alarm system shall of fire survival type. For fire detection, contractor may also use mineral insulated cable complying with CWZ category of BS6387.

e) In addition Screening to be applied on each pair as per BS EN 50288.

A16.3.20.2 **Conductors**

a) The conductors shall be of stranded, high conductivity annealed copper wires complying with BS 6360/**BS 60228**.

b) Flexible cables and cables for fixed installations shall have stranded conductors.

c) Conductors shall be smooth, uniform in quality, free from scale, spills, splits and any other defects. There shall be no joints in individual strands.

d) All signal /control copper armoured cables shall be rated at 600 / 1000 V whilst non-armoured cables shall be rated at 450 / 750 V and have a minimum cross sectional area of 2.5 mm^2.

A16.3.20.3 **Screening**

a) Screening shall be achieved by the use of laminated tape, consisting of an aluminium foil bonded to a polyester film for the strength, applied to the cable with an overlap so that full 100 % coverage of the conductors is afforded.

b) The cable shall be individually screened pair cables to provide improved cross talk immunity characteristic if required.

c) A drain wire or continuity conductor, laid under and in contact with the aluminium foil shall be provided. The tinned annealed copper conductor may be of solid or strand construction, using the approved manufacturing technique.

d) The maximum resistance of the drain wire or continuity conductor provided shall meet with the requirements of **BS EN 50288-7**.

A16.3.21 **Storage: -**

a) Contractor shall take proper care to avoid deterioration of drums or their becoming a hazard to the general public.
b) Contractor shall ensure that safe handling of drums as per BS 8512.
c) Battens, where applied, should not be removed from drums until the cable is about to be installed.
d) Contractor shall ensure that incineration of scrap cable should only be under taken by licensed contractor.

Section A17: CABLE CONTAINMENT SYSTEM

TABLE OF CONTENTS

A17.0 CABLE CONTAINMENT SYSTEM

A17.0 CABLE CONTAINMENT SYSTEM

A17.1 General

A17.1.1 This Section specifies the manufacture and installation of cable tray, cable trunking, cable ladder, ducts and conduits.

A17.2 Standards

A17.2.1 **Relevant Codes and Standards**

A17.2.1.1 BS 476: Part 6: Fire tests on building materials and structures. Method of test for fire propagation for products only for conduits

A17.2.1.2 IEC 61537 : Requirements and tests for cable tray systems and cable ladder systems intended for the support and accommodation of cables and possibly other electrical equipment in electrical and/or communication systems installations. Where necessary, cable tray systems and cable ladder systems may be used for the segregation of cables.

A17.2.1.2 BS 476: Part 7: Fire tests on building materials and structures. Method of test to determine the classification of products based on surface spread of flame only conduitsA17.2.1.3 BS 729/IS 4759: Specification for hot dip galvanized coatings on iron and steel articles.

A17.2.1.4

A17.2.1.5 BS 970: Part 3/**10277/ 10278**: Specification for wrought steels for mechanical and allied engineering purposes. Bright bars for general engineering purposes.

A17.2.1.6 BS 1449: Part 1: Steel plate. Sheet and strip. Carbon and carbon-manganese plate, sheet and strip.or IS: 10748: Specification of Hot Rolling SWteel Strips for welded tubes and pipes

A17.2.1.7 BS 7371-12: Coatings on metal fasteners. Requirements for imperial fasteners or equivalent IS

A17.2.1.8

A17.2.1.9

A17.2.1.10 **BS 61386: Part 1: Conduit systems for cable management. Generalrequirements**

A17.2.1.11 BS 4678: Cable trunking.

A17.2.1.12 BS 4678: Part 1: Cable trunking. Steel surface trunking.

BS 50085: Part 1 and 2: Cable trunking systems and cable ducting systems for electrical installations

A17.2.1.13 BS 7671: Requirements for electrical installations. IEE Wiring Regulations.Sixteenth edition.

A17.3 Technical and Installation Requirements

A17.3.1 General

A17.3.1.1 Material for use in cable containment system including their surface finish materials shall be capable of being subjected to temperatures up to 500 degree Celcius for an hour and shall not support combustion under the same temperature conditions.

A17.3.1.2 All cable containment ducts, particularly concrete cable ducts shall be sloped toward manhole or box from which water may be drained or pumped.

A17.3.1.2 All cable tray and Cable Ladder systems shall be in accordance of IEC 61537 or NEMA VE 1

A17.3.2 Installation of Cable Containment System, Supports and Hangers

A17.3.2.1 All steel components shall be hot-dip galvanized to BS 729/ IS 4759 after manufacture. Where an exposed galvanised surface has been cut or otherwise damaged it shall be repaired by application of a zinc rich epoxy primer.

A17.3.2.2 The use of rag bolts, indented bolts, foundation bolts or similar fixings requiring grouting shall not be permitted.

A17.3.2.3 Where supports have to be carried on structural steelwork, they shall be attached to the steelwork by means of girder clips, beam clamps or other proprietary attachment devices not requiring drilling or welding of the steelwork.

A17.3.2.4 Where trays or ladders cross open spaces or in other locations where no structure is available on which to fix cable supports, suitable fabricated steel auxiliary supporting structures shall be provided subject to approval by Employers Representative.

A17.3.2.5 Where tray and ladder systems are supported by drop rods additional restraints shall be included to provide adequate lateral support. Restraints shall be installed at all bends and intersections and at intervals not exceeding 15m on straight runs. Support rods shall be at least 6 mm diameter. Trapeze or other hangers shall be clamped on the drop rods between two nuts.

A17.3.2.6 Support channels shall be the basic structural members of the system and shall be easily fixed to the floors, walls or ceilings as necessary and may be interconnected in a multitude of ways by using different brackets. All components shall be fitted together using bolts, spring washers and channel nuts.

A17.3.2.7 The channels shall be cold rolled from 2.6 mm mild steel with a hot dip galvanised finish, to BS 729 orIS 4759 . In environment with excessive humidity, the cable containment system shall be protected with an approved coating.

A17.3.2.8 Channel nuts shall be inserted into the channel as necessary along its length, and a 90° clockwise turn of the nut shall clip each nut firmly into position. Each channel nut shall have two parallel grooves on its outside face with teeth along its length.

A17.3.2.9 Channel nuts shall be manufactured from steel bar, to BS 970: Part 3/**BS 10277/10228** and shall be zinc plated to. BS 7371-12 or equivalent IS Channel nuts of M6, M10 and M12 screw threads shall be used as appropriate to meet specified requirement based on the working drawing approved by Employers Representative.

A17.3.2.10 The standard fixing bolts for use throughout the system shall be M10 or M12 high tensile, hexagon head set screws to BS 3692-8.8. The standard finish for these bolts shall be zinc plated to. . BS 7371-12 or equivalent IS

A17.3.2.11 For fixing cable tray to tray arms, tray brackets or cantilever arm, M6 by 16 mm bolt shall be used, unless otherwise specified.

A17.3.2.12 Brackets and fittings shall be attached to the channel using bolts, spring washers and channel nuts. Standard fittings shall be used for the attachment of cable tray to a framework.

A17.3.2.13 Acceptance tests for the safe carrying load for each bracket at typical locations shall be established by the Contractor during preparation of working drawings for the Employers representative’s consent.

A17.3.3 Cable Trays and Ladders

A17.3.3.1 **General**

a) Cable trays shall be of a perforated factory-made type complete with factory made bends, tees and fixing accessories. The cable trays shall be made from mild steel sheet, complying with BS 1449: Part 1 / IS10748 and shall be hot-dipped galvanised after perforation. Cable trays shall have corrosion protection not less than Class 2 to,**BS 50085: Part 1 and 2.**

b) All cable trays and ladders installed in stations and tunnels shall be capable of being subjected to temperatures up to 500 °C for one hour and conform to National Electrical Code (NFPA 70).

c) The cable tray/ladder shall be of sufficient width to take the cables without crowding and shall allow for future additions to the proportion of 25-30 % of present requirements. Contractor shall prepare Working Drawings based on actual cable routing and above mentioned spare capacity and obtain consent of Employers Representative. Double stacking of cable shall not be allowed except where specifically agreed by the Employers Representative

d) Hot dipped galvanised cable trays and supports used within damp environment shall be protected with an approved coating. All the cable trays shall be of heavy duty with return flange type **All cable tray sizes 450mm and above shall be of heavy duty type with return flange. All cable tray below 450mm shall be with standard configuration.**

e) Widths of cable trays, thickness of steel, flanges of trays, and bends or tees, shall be nominally as follows:

Width of Tray (mm)	Thickness of Steel (mm)	Flanges of Tray (mm)
300 & below	1.5	35
300-450	1.6	35
450-900	2	35
1000	2	50

f) All trays / ladders that are cut for installation shall be made good by first treating the surfaces with a suitable rust-proofing agent, similar to that used in the original manufacture, and then shall have their ends painted with a zinc coating to ensure continuous protection.

g) Trays / ladders shall have suitable strength and rigidity to provide adequate support for all contained cabling.

h) Steel trays and ladders shall be supported so that the maximum deflection between supports is 1/360th of the span length.

i) Midspan joints shall be located as close as practical to one-quarter of the span distance away from a support position. Joints at mid-span or directly over supports shall be avoided. Supports shall be provided within 150 mm of all accessories.

j) Cable trays / ladders shall not present any sharp edges, burrs, or projections that could damage the insulation or sheathing of the cables.

k) Each run of cable tray/ladder shall be completed and cleared of debris before the installation of any cables.

l) Sufficient space shall be provided and maintained above the cable trays to permit adequate access for the installation and maintenance of the cables. Where a cable tray / ladder is suspended from the ceiling, wall or structure, it shall be supported by hot dipped galvanized steel supports or hangers of Approved design.

m) Cable ladders shall be used for supporting cables of bigger size. Cable trays shall be used for cables of smaller sizes, control cables and wires.

A17.3.3.2 **Cable Tray Installation**

a) Where two straight lengths of cable tray are joined together, an external coupler or joint plate shall be used to prevent any sag or bending at that point. The coupler or joint plate shall be joined to each length of the tray by means of not less than two non-corrosive round-headed screws fixed from the inside of the tray.

b) All bends and tee's shall be 90° bends or tee-offs with minimum 50 mm inside bend radius. Cable bends in cable trays shall be such that the bending radius of the largest cable to be clipped to the tray shall not exceed the bending radius limits as specified in BS 7671.

c) The cable trays shall be fixed in such a manner that it is rigid throughout its length with a minimum of 13mm clearance between the tray and the structure.

d) Cable trays shall be adequately supported. Fixing of cable trays shall be provided at regular interval not exceeding 1.2m and on both sides of and at a distance not exceeding 225 mm from, a bend or intersection especially where bends and tee joints are fitted to the trays.

e) Where cable trays pass across structure movement/expansion joints, the cable trays shall be physically separated by a gap of width equal to the joint it is crossing. To maintain electrical/earth continuity of the cable trays a 150mm^2 copper flexible earth continuity conductor shall be installed across the gap and secured to each end of the cable trays.

f) Where cables are required to pass through the tray, or over the lip of the cable tray, a low smoke halogen free grommet or packing section shall be installed to protect the cable sheath from sharp edges.

g) Where cables pass through wall openings the cable tray shall be installed in such a manner as to support the cables as they pass through the wall opening.

A17.3.3.3 **Cable Tray Earthing**

(a) Each joint shall have a 6 mm ^{2}tinned copper bond bolted to each adjacent tray to ensure electrical continuity. The cable tray systems shall be bonded to the earthing system by use of LSZH insulated stranded single core Copper cable.

A17.3.3.4 **Cable Ladders - Additional General Requirements**

a) Cable ladder shall be NEMA VE 1 class 8C/ IEC 61537 and sizes according to loading, number and diameter of cables.

b) The complete cable ladder system shall be designed so that drilling will not be necessary on site and cutting will be kept to a mini mum.

c) Cable ladders shall be manufactured from 2mm thick mild steel and hot-dip galvanized to BS 729 or IS 4759. The two side rails of the cable ladder shall be of minimum 40mm in height with returns at top flange to gain extra strength. The rung shall be spaced at approximately 250mm centres with sufficient width for various cable fixing methods including nylon tiles, saddles and perforated strips, cable clamps and cleats.

d) Factory standard right-angle bends, tee junctions, off-set reducers, straight reducers shall be used for horizontal bends, vertical bends, branching out and reduction of cable ladder width. Factory standard expansion splice plate shall also be provided to allow for expansion and contraction of the cable ladders.

e) All clamping nuts, bolts, washers etc. shall be hot-dipped galvanized to BS 729 or equivalent Indian standards.

f) Vertical runs of cable tray or ladder shall not be installed such that they straddle vertical expansion joints of the building structure.

g) Notwithstanding the above, complete cable ladder system shall be electrically continuous.

A17.3.3.5 Cable Ladders Installation The same requirements as specified cable tray installation, Clause A17.3.3.2, shall apply.

A17.3.3.6 Cable Ladder Earthing The same requirements as specified cable tray earthing, Clause A17.3.3.3, shall apply.

A17.3.4 Cable Trunking

A17.3.4.1 **General**

a) Trunking and fittings shall comply with BS 4678: Part 1/**BS 50085: Part 1 and 2** or equivalent Indian Standards. Factory fabricated bends and tees shall be used.

b) Trunking shall be top accessed. Inverted trunking is not acceptable.

c) All multi-compartment trunking systems shall maintain the stated segregation throughout, including all accessories. Sub-main cables shall be laid in a single layer.

d) Trunking shall be manufactured in mild-steel sheet and shall be hot-dip galvanized. Trunking shall have a removable cover throughout its length with centre-screw latch fixing, or quick-fixing device to the Employers Representatives approval, sizes up to 100mm by 100mm shall be 1.6mm thick and from 150mm by 75mm up to 150mm by 150 mm shall be 1.8mm thick. Spring clip type cover shall not be used. The trunking shall normally be supplied in 2400mm lengths. Lengths of trunking, bends tee sections and offsets shall be coupled together by means of fish plates and the trunking manufacturer’s cadmium plated steel set screws, nuts and shake proof washers. At each joint in the trunking, continuity shall be maintained by means of copper links, not less than 25 x 3 mm to achieve an acceptable earth loop impedance level in compliance with BS 7671, fixed with brass nuts, bolts and serrated washers. Links shall be supplied by the trunking manufacturer at no extra cost to Employer. Removal of any lid no matter how it is fitted shall not affect the earth continuity of the trunking. LSZH copper cable link with cable lugs may be used, if the proper connection method is provided to avoid long term corrosion and electrolytic action. The LSZH cable shall have an equivalent cross sectional area to the copper links. Bonding link shall be fixed on external surfaces.

e) Manufacturer's standard fittings shall be used for all connections and changes of direction. All bends, tee pieces, stop ends, outlets, intersections and adapters shall be of the same manufacturer as the trunking. Trunking shall not be cut or bent to form bends, flanges or attachments. Gusset bends shall be used wherever necessary to provide sufficient bending radius for the cables. Site fabricated items shall not be accepted

f) Hot dipped galvanised trunking used in damp environment shall be protected by an Approved coating.

g) The minimum size shall be 50mm by 50mm.

h) All inside edges of trunking shall be smooth and provision shall be made to prevent abrasion at bends.

i) Cable retaining straps supplied by the trunking manufacturer shall be fitted at intervals not exceeding 1m. Where trunking passes through walls, floors and ceilings, proprietary fire barriers shall be installed in the trunking. The fire barrier shall have a rating not less than that of the original construction of the opening.

j) Trunking shall be adequately supported throughout its length. Trunking support and channel shall be quick-fixing type and shall be such as to space the trunking a minimum of 13mm from any part of the wall or bulkhead. The maximum spacing between fixings shall be as follows:

Trunking Size	Maximum Distance
up to 50 mm by 50 mm	900 mm
up to 75 mm by 75 mm	1200 mm
up to 150 mm by 150 mm	1500 mm
above 150 mm by 150 mm	1800 mm

k) A minimum of two fixings shall be provided between joints in the trunking except where the distance between is less than the maximum spacing.

l) Where trunking is suspended, the suspension shall be rigid. At the suspension point the trunking shall be reinforced by a plate or washer of minimum thickness 3mm or 10 SWG whose cross-sectional area shall not be less than half that of the trunking (cross-sectional area). Unless additional stiffening is provided, the spacing between suspension points shall not be greater than those shown above.

m) Where trunking is cut or drilled, the cut edges of the trunking shall be smoothed to prevent abrasion of the cables and shall be painted with anti-corrosion paint, to the same colour as the adjacent surfaces, such painting to be carried out as the work proceeds. In no circumstances will rough screw edges and nuts be allowed in the interior of the trunking. Round headed screws of a non-corrosive material shall be used when installing trunking. The round screw heads shall be on the interior of the trunking.

n) Flush or buried trunking and under floor metal ducts shall comply with BS 4678.

o) The space factor for cables installed in trunking shall not exceed 45%.

p) All lengths of vertical run trunking in excess of 3000mm, shall contain cable supports made of insulating, non-hygroscopic, non- ombustible material. The spacing between such supports shall not exceed 1800mm. An additional support shall be provided at the top of all vertical runs exceeding 3000mm, to support the weight of the cable and distribute the cables within the trunking to prevent undue compression of the installation.

q) Where trunking crosses expansion joints, a trunking fitting shall be used which shall allow for expansion and maintain earth continuity.

r) Suitable cutout on underfloor trunking at ticket barriers shall be provided to suit Automatic Fare Collection System Contractor's requirement. The cutout shall not have a sharp edge or abrasive effect on cables. The location and route for the cutout and under floor trunking shall be according to Working Drawings.

s) Trunking installed externally shall be manufactured from galvanized sheet steel in accordance with BS 4678: Part 1/ **BS 50085: Part 1 and 2** or equivalent Indian Standards. . Trunking installed internally shall be of Class 2.

t) Partitions or dividers shall be of the same material and finish as the trunking. The method of fixing shall not cause any long-term corrosion or electrolytic action.

u) Connections to multiple boxes, switchgear and distribution boards shall be made with flanged units or bell mouths. Expansion joints in long continuous runs shall be provided as recommended by the manufacturer

A17.3.5 Ducts

A17.3.5.1 The term "ducts" in this clause shall mean any pipe, open or covered trench or cavity formed for the specific purpose of routing electrical and/or other services and shall be other than electrical conduits, trunking and cable trays.

A17.3.5.2 Ducts into which cables are to be drawn shall be such that the usable spare capacity is not less than 50%.

A17.3.5.3 Care shall be taken to make the bends of pipe or duct lines as easy as practicable. In no case shall the radius be less than 6 times the outer diameter of the duct circumference, or 6 times the minor dimension of the duct if rectangular.

A17.3.5.4 Before drawing or installing cables in the duct, the duct shall be clean, dry and free from obstructions and of adequate size for the cables to be installed, having particular regard for the separation from other services and to the provision of adequate drawing pits, covers and markings, and allowances for bending radii. Adequate provision shall be made for cables entering or leaving ducts. Draw wires shall be provided wherever appropriate.

A17.3.5.5 All cables run in open ducts or in ducts shared with other services, shall be adequately secured to the wall of the duct by type saddles or hangers.

A17.3.5.6 Adequate precautions shall be taken to ensure that there is no interference to the cables from the other services both mechanically and electrically.

A17.3.5.7 Trunking shall be used within a duct, only where specified.

A17.3.5.8 No materials other than completely water-proof materials shall be installed in any duct.

A17.3.5.9 The duct shall be sealed to prevent the entry of water or vermin.

A17.3.6 Not used

A17.3.7 Penetration in walls

A17.3.7.1 Where proprietary cable transits are required, they shall be installed strictly in accordance with the manufacturer's recommended procedures. Where cables pass through walls, floors, or fire partitions, sleeves shall be installed to facilitate installation and subsequent withdrawal of the cable.

A17.3.7.2 After installation of the cables, the hole(s) through which the cables pass shall be sealed with fire resisting material to achieve the fire rating as the structure through which they pass. Details of the proposed sealing method shall be submitted for approval prior to implementation. Cables passing through external walls shall additionally be sealed with appropriate additional weather protection to prevent the ingress of water.

A17.3.7.3 The fire resisting material shall intumesce to form a hard char that tightly sealspenetrations against flame spread, smoke and toxic fumes. The fire resisting material shall be tested according to ASTM E119, ASTM E814 and ASTM E84. Test certification and test report shall be submitted.

A17.3.7.4 The materials shall emit toxic gases on exposure to fire. The materials shall be easy to dismantle and replace in case of rearrangement and also withstand vibration due to rail operation and seismic tremor.

A17.3.8 Conduit and Accessories

1. **Detailed Description and Application in DMRC for Conduit and Accessories**

Supply and Installation of Rigid Steel Conduits, Associated Fittings and Accessories:

Conduit is a part of closed wiring system of circular or non- circular cross-section for conductors and/or cables in electrical installations allowing to draw them in and/or to replace them. However, in this document the word 'conduit' shall refer to circular cross- section only. Conduits shall be sufficiently closed- jointed so that the conductors can only be drawn in and not inserted laterally. The conduits shall be rigid Steel type.

Conduit Fittings referred to in this document is a device designed to join or terminate one or more portions of a conduit installation which shall be of metal (Galvanized Steel) only.

Conduit Accessories are the parts other than fittings used in fixing steel conduits.

The specifications contained herein are applicable to Elevated/ Underground/ At Grade stations, Depots, Staff Quarters and office Complex etc.

Governing Specifications

The conduits, associated fittings and accessories shall satisfy the requirements given below and shall also comply with standards mentioned particularly in the table below unless otherwise stipulated in the specifications. The latest version of standards shall be applicable.

Specification For Conduits For Electrical Installations: Part I General Requirements, Part II Rigid Steel Conduits	IS: 9537 : Part I, 1980 IS: 9537: Part II, 1981
Specification For Accessories For Rigid Steel Conduits For Electrical Wiring	IS: 3837 : 1976
Conduit Fittings for Electrical Installations: Part1 General Requirements Part 2: Metal Conduit Fittings	IS: 14768 Part-1, 2000

	IS: 14768 Part-2, 2003
Specification for Flexible Steel conduits for electrical wiring	IS: 3480 : 1966
Code of practice for electrical wiring installations	IS: 732 : 1989
National Electrical Code, 2011	
National Building Code, 2005	
Central Electricity Authority (Measures relating to Safety and Electricity Supply) Regulations, 2010	
Plugs And Socket-Outlets of Rated Voltage up to and Including 250 Volts And Rated Current up to and Including 16 Amperes — Specification	IS: 1293 : 2005
Switches for domestic and similar purposes	IS: 3854 : 1997
General Requirements for Enclosures for Accessories for Household and Similar Fixed Electrical Installations –Specification	IS: 14772:2000
Code of practice for electrical installation fire safety of buildings	IS: 1646: 1997
Recommendations on safety procedure and practices in Electrical works	IS: 5216 : 1982
Specification for Hot-dip Zinc coating on mild steel tube	IS: 4736 : 1986
Methods For Determination of Mass of Zinc Coating on Zinc Coated Iron and Steel Articles	IS: 6745 : 1972
Plugs, Socket-Outlets and Couplers for Industrial Purposes, Part 2: Dimensional Interchangeability Requirements for Pin and Contact-Tube Accessories	IS: 60309-2
Degrees of protection provided by Enclosures (IP Code)	IS: 60529
Recommended Practice for hot-dip galvanizing of Iron and Steel	IS: 2629
Zinc Ingot- Specifications	IS: 209
Hot Rolled Carbon Steel Sheet and Strip Specifications	IS: 1079
Standard Test Method for Surface Burning Characteristics of Building Materials	ASTM E84
Standard Test Methods for Fire Tests of Building Construction and Materials	ASTM E119
Standard Test Method for Fire Tests of Penetration Fire stop System	ASTM E814

Note: The latest edition of the standards shall be used. Wherever Indian Standards are not available, relevant latest British and/or IEC Standards shall be applicable.

1.1. Abbreviations

- IS- Indian Standard
- IEC- International Electrotechnical Commission
- ERW- Electric Resistance Welding
- GI- Galvanized Iron
- MS- Mild Steel
- NEC- National Electrical Code
- NBC- National Building Code
- ASTM- American Society for Testing and Materials

Note: The term 'Approved' in this specification means that the approval of the Engineer-in- Charge shall be taken.

2. Requirement

2.1. Rigid Galvanized Steel Conduits (IS: 9537, Part I & II)

These shall be galvanized steel with minimum wall thickness of 1.6mm up to 32mm diameter and 2.0mm for sizes above 32mm diameter, electric resistance welded (ERW), electric threaded type, with both ends screwed having perfectly circular tubing. Conduits shall show no appreciable unevenness and shall be free from burrs, fins and the like which may cause damage to cable insulation. These rough internal edges shall be removed by means of a proper reamer. Conduits shall be precision welded and shall be fabricated from tested steel strips of required thickness by electric resistance welding. Welds shall be smooth and consistently of high quality to ensure crack proof bending. The conduit shall be galvanized according to IS 4736-1986. All conduits used in this work shall be marked according to IS: 9537 Part-2 and also with ISI certification mark. Other requirements for the conduits shall be as per IS: 9537, Part-1 and Part-2.

2.2. Flexible Conduits (IS: 3480)

The usage shall be restricted to only those areas where it is not possible to use Rigid Steel Conduits. All final connections especially to vibrating equipments shall be made through flexible conduits. Flexible steel conduits shall be as per latest edition of IS: 3480. Where flexible steel conduit is employed, the length shall not exceed 2.5 metres and shall be provided with an earth continuity conductor of copper size not less than 2.5mm^2.

2.3. Galvanized Steel Bends (IS: 14768)

Large right angle bends (as per IS: 14768 but more than 75mm radius) or non-right angle bends (as per IS: 14768) in conduits runs shall be made by means of conduits bending machines carefully so as not to cause any crack in the conduit. Small right angle bends in conduits runs can be made by standard conduit accessories (solid/inspection bends/elbows). Facilities such as draw-in boxes must be provided so that cables are not drawn round more than two right-angle bends or their equivalent. The radius of bends must not be less than the standard normal bend. Bends in multi runs of conduits shall be parallel to each other and neat in appearance, maintaining the same distance as between straight runs of conduits.

2.4. Standard Fittings & Accessories IS: 3837 & IS: 14768, Part-1 and Part-2.

Heavy Protection Class Galvanized (IS 4736 & IS 6745) standard conduit fittings and accessories like standard/extra-deep circular boxes, looping in boxes, junction boxes, solid / inspection elbows, solid/inspection tees, couplers, nipples, saddles, check nuts, earth clips, bushes etc. shall be of superior quality and of approved makes. The covers screwed with approved quality screws shall be used that can withstand hard use or wear. Samples of all conduits fittings and accessories shall be got approved by Engineer-in-Charge before use. Conduit fittings and Accessories shall be as per IS: 3837 and IS: 14768, Part-1 and Part-2.

Conduit boxes and covers shall have a minimum degree of protection as follows:

Description	Against Corrosion	Enclosure	Surface or Concealed
Outside buildings	Heavy Protection both inside and outside	IP 54	Surface

Plant rooms and service ducts, Switch Rooms, Store Rooms, Ceiling Voids	Heavy Protection both inside and outside	IP 41	Surface
Below Ground	Heavy Protection both inside and outside	IP 44	-
All other locations	Heavy Protection both inside and outside	IP 41	Concealed

The contractor shall submit for approval the ‘Method Statement including Tests’ to ensure above degree of ingress protection. In case no testing facility is available, the contractor shall comply with this clause by submitting design and installation features.

2.5. Fabricated Fittings & Accessories

Wherever required, outlet/ junction boxes of required sizes shall be fabricated from 1.6mm thick MS sheets except ceiling fan outlet boxes which shall be fabricated from minimum 3mm thick sheets. The outlet boxes shall be galvanized and of approved quality, finish and manufacture. Suitable means of fixing connectors etc., if required, shall be provided in the boxes. A screwed brass stud shall be provided in all boxes except circular junction boxes as earthing terminal.

a) Outlet Boxes for Light Fittings

These shall be minimum 75mm x 75mm x 50mm deep and provided with required number of threaded collars for conduit entry. For ceiling mounted fluorescent fittings, the boxes shall be provided 300mm off center for a 1200mm fitting and 150mm off center for a 600mm fitting so that the wiring is taken directly to the down rod. 3mm thick Perspex/hylam sheet cover of matching color shall be provided.

b) Outlet Boxes for Ceiling Fans

Outlet boxes for ceiling fans shall be fabricated from minimum 3mm thick MS sheet steel and galvanized. The boxes shall be hexagonal in shape of minimum 100 mm depth and 60mm sides. Each box shall be provided with a recessed fan hook in the form of one ’u’ shaped 15 mm dia rod welded to the box and securely tied to the top reinforcement of the concrete slab for a length of minimum 150 mm on either side. 3mm thick Perspex/hylam sheet cover of matching colour shall be provided.

2.6. Boxes for Modular Wiring Accessories

Boxes for housing modular wiring accessories (switches, switched socket outlets, telephone/computer / TV outlets, bell pushes, electronic fan regulators etc.) shall be fabricated from minimum 1.6mm thick MS sheets provided with rust inhibiting galvanization. The MS boxes shall be suitable for a grid plate being fixed over it for mounting wiring accessories leaving ample space at the back and on the sides for accommodating wiring conductors, MS boxes shall be provided with a brass earth terminal. The MS boxes shall have knockout holes for conduit entry which shall be secured in position by check nuts and provided with bushes.

In case the number of switches in one box is not tallying with that available in standard manufacturer range, the box accommodating the next higher number of switches shall be provided without any extra cost.

2.7. Wiring Capacity of Conduits

Conduits shall be of ample sectional area to facilitate simultaneous drawing of wires and permit future provision also. Total cross section of wires measured overall shall not normally be more than half the area of the conduit.No cables

Nominal cross sectional area of conductor in sq.mm	*20 mm*		*25 mm*		*32 mm*		*38 mm*		*51 mm*		*64 mm*	
	S	*B*	*S*	*B*	*S*	*B*	*S*	*B*	*S*	*B*	*S*	*B*
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*
1.50	5	4	10	8	18	12	–	–	–	–	–	–
2.50	5	3	8	6	12	10	–	–	–	–	–	–
4	3	2	6	5	10	8	–	–	–	–	–	–
6	2	–	5	4	8	7	–	–	–	–	–	–
10	2	–	4	3	6	5	8	6	–	–	–	–
16	–	–	2	2	3	3	6	5	10	7	12	8
25	–	–	–	–	3	2	5	3	8	6	9	7
35	–	–	–	–	–	–	3	2	6	5	8	6
50	–	–	–	–	–	–	–	–	5	3	6	5
70	–	–	–	–	–	–	–	–	4	3	5	4

system outlets in wall shall be provided with molded cover plates of shape, size and colour approved by the Engineer- in- Charge made from high impact resistant, flame retarding and ultra violet stabilized engineering plastic material, and secured to the box with counter sunk round head chromium plated brass screws. Where two or more switches are installed together, they shall be provided with one common switch cover plate as described above with notches to accommodate all switches either in one, two or three rows.

One and two gang switch cover plate, telephone outlet cover plate, 6 A and 16 A switched / unswitched plates, shall have the same shape and size. Three and four gang switch cover plates shall have the same shape and size. Six and eight gang switch cover plates shall have the same shape and size. Nine and twelve gang switch cover plates shall have the same shape and size. Wherever five switches, seven switches, ten switches and eleven switches are to be fixed the next higher sizes of gang switch cover plate to be used and openings shall be provided with blank-off covers at no extra cost.

2.8.3. Wall Socket Outlets

All 6/16 A wall sockets outlets unless otherwise mentioned on the drawings shall be switched, with round pins and fitted with automatic linear safety shutters to ensure safety from prying fingers. Unswitched 6/16 A wall socket outlets where called for in the drawings shall be of three pin type. . The socket outlets shall be made from high impact resistant, flame retarding and ultra violet stabilized engineering plastic material. For underground stations, the cover plates of socket outlets shall be AISI Type 304 stainless steel in public area and standard plaster for staff/ back of house areas. Socket outlets mounted externally or in damp areas shall be weatherproof and shall have a degree of protection of IP54. The switch and sockets shall be located in the same plate. The plates for 6A switched / unswitched plugs and telephone outlets shall be of the same size and shape. All the switched and unswitched outlets shall be of the best standard. Mounting boxes shall be galvanized steel. The switch controlling the socket outlet shall be on the phase wire of the circuit. An earth wire shall be provided along the cables feeding socket outlets for electrical appliances. The earth wire shall be connected to the earthing terminal screw inside the box. The earth terminal of the socket shall be connected to the earth terminal provided inside the box.

2.8.4. Industrial Socket Outlets

Industrial plugs, connectors, socket outlets and appliance inlets shall be provided to meet IS 60309-2. Heavy- duty three phase socket outlets shall be 32A, complying with IS 60309-2. For interior use such as plant room unit shall be rated to IP44. Externally or in wet environments such as Tunnel and Undercroft level the protection shall be IP66.

2.9. Conduit Installation (IS: 732 and Relevant clauses of NEC, 2011)

2.9.1. System

The whole conduit system shall be installed to comply fully with relevant provision in Indian Standard Specifications, National Electrical Code, 2011. Conduits shall be laid either recessed in walls and ceilings or on surface on walls and ceilings or partly recessed and partly on surface, as required. Same rate shall apply for recessed and surface conduiting in this contract. Steel wire of 1.6 mm^2 size to serve as a fish wire shall be left in all conduit runs to facilitate drawing of wires after completion of conduiting. No conduit shall be under mechanical stress. When crossing through expansion joints in building, the conduit sections across the joint shall be through approved quality metallic flexible conduits (as per IS 3480) of the same size as the rigid conduit. Allowance shall be made for running an earth wire of size not less than the largest conductor contained between each terminal fitted in the nearest conduit boxes on each side of the telescopic/ flexible conduit joint.

2.9.2. Layout

Conduits layout and routes shall be submitted for Engineer-in-Charge's approval prior to execution. Allowance for adjustments due to site conditions shall be provided with no extra cost.

Conduit routes shall be chosen for easy, straight runs with a minimum of bends and crossing. Generally they shall follow the structure of building, running at right angles or in parallels to floors and ceiling. Conduit shall be kept within 300mm of floors and ceiling when running parallel to them.

Outlets boxes for housing accessories shall be used as draw boxes. The total number of draw boxes shall be kept to a minimum and shall be provided so that conduits runs do not exceed 8m or have more than two right angle bends.

Conduits from different distribution boards shall not be connected to the same junction box. Each run of conduit shall be assembled complete with draw in wires.

2.9.3. Joints and Terminations

Conduit threads shall be thoroughly cleaned and the conduits tightly screwed. The conduit system shall be watertight after installation. The contractor shall submit for approval the 'Method Statement including Tests' to ensure the above requirement.

Conduits shall be connected using couplers or via boxes. With a coupler, the ends of the conduit shall be butted close together and the running coupler is screwed tightly on and tightened by a locknut.

Conduits terminating into boxes provided with spouts shall be threaded so that there are no exposed threads. For boxes with no spouts, the termination shall be made using a brass bush and a coupler. The conduit is pushed through the knockout or drilled entry and the bush is screwed tightly onto its end. The coupler is screwed to butt firmly against the exterior wall of the box.

Where conduits are not jointed or terminated in boxes, they shall be terminated in a screwed brass bush.

In all joints and terminations, conduits threads shall not be exposed. Where this cannot be avoided as in a running coupler, the exposed threads shall be treated as given in Section 4(b) of this specification.

2.9.4. Bends (IS: 14768-2)

Conduits shall be bend cold with an approved type of bending block or bending machine, without altering the dimensions of their sections. The approval for the bending block or bending machine proposed to be used at site shall be taken from the Engineer-in- Charge.

All conduits bends shall be such as to permit compliance to the requirements for bends in the IS regulations.

Bends shall be made with as large a radius as the position of the conduit within the building permits. Where the bend is more than 90 degree, circular or rectangular junction boxes shall to be used for connecting conduits.

2.9.5. Recessed Conduiting

Conduits recessed in concrete members shall be laid before casting, in the upper portion of slabs or otherwise as may be instructed, so as to embed the entire run of conduits and ceiling outlet boxes with a cover of minimum 12mm concrete. Conduits shall be adequately tied to the reinforcement with steel wire of not less than 1.5mm diameter to prevent displacement during casting at intervals of maximum 1 metre. No reinforcement bars shall be cut to fix the conduits. Suitable flexible joints shall be provided at all locations where conduits cross expansion joints in the building. Spacing between concealed conduits entering the draw-in boxes shall not be less than 25mm to allow concrete aggregate to pass and set between conduits.

Conduits recessed in brick work shall be laid in chases to be cut by electrical contractor in brick work before plastering. The chases shall be cut by a chase cutting electric machine. The chases shall be of sufficient width (minimum 10mm spacing between adjacent conduit) to accommodate the required number of conduits and of sufficient depth to permit full thickness of plaster (minimum 6mm) over conduits. The conduits shall be secured in the chase by means of heavy duty pressed steel clamps screwed to MS flat strip saddles at intervals of maximum 600 mm.The chases shall then be filled with cement and coarse sand mortar (1:3) and properly cured by watering. Galvanized chicken wire mesh of 0.6mm thick with 10 to 15mm aperture shall be provided for the full length and width of the chase in the plaster to prevent cracking.

Junction boxes intended for facilitating drawing of wires in conduiting system shall be located in accessible locations to permit redrawing of wires in future. Open ends of conduits laid in slabs and walls shall be suitably plugged before pouring concrete/plastering to prevent ingress of water / debris in to the conduits.

Entire recessed conduit work in concrete member and in brick work shall be carried out in close coordination with progress of civil works. Conduits in concrete member shall be laid before casting and conduits in brick work shall be laid before plastering. If it becomes necessary to embed conduits in already cast concrete members, suitable chase shall be cut in concrete for the purpose. For minimizing this cutting, conduits of lesser diameter than 25mm and outlet boxes of lesser depth than 50mm could be used by the contractor for such extensions only after obtaining specific approval from Engineer-in-Charge. For embedding conduits in finished and plastered brick work, the chase would have to be made in the finished brick work. After fixing conduit in chases, chases shall be made good in most workmanlike manner to match with the original finish.

Cutting chases in finished concrete or finished plastered brick work for recessing conduits and outlet boxes etc. shall be done by the Contractors without any extra cost.

In the concealed conduit system, all boxes for accessories & draw/junction boxes shall be installed such that outer rim is flush with the finished surface of the wall. Sockets near skirting level shall be fed from the floor above rather than the floor below, because in the latter case it would be difficult to avoid traps in the conduit

Where surface mounted distribution boards are used with a sunk conduit, a flush adaptable box shall be fitted in the wall behind the distribution board and to take the flush conduits directly into it. Holes can be drilled in the back of the distribution board and bushed. Spare holes should be provided for future conduits. Distribution boards must be bonded to the adaptable boxes and unused holes should be sealed.

2.9.6. Surface Conduiting

Wherever so desired, conduit shall be laid in surface over finished concrete and/or plastered brickwork. Suitable spacer saddles of approved make and finish shall be fixed to the finished structural surface along the conduit route at intervals not exceeding 600mm (except from fitting where 300mm). Fixing of standard bends or elbows shall be avoided as far as practicable and all curves maintained by bending the conduit pipe itself with a long radius which will permit easy drawing-in of conductors. Holes in concrete or brick work for fixing the saddles shall be made neatly by electric drills using masonry drill bits. Conduits shall be fixed on the saddles by means of good quality Galvanized steel clamps meant to withstand hard use and wear screwed to the saddles by counter sunk screws. Neat appearance and good workmanship of surface conduiting work is of particular importance. The entire conduit work shall be in absolute line and plumb. Conduits above false ceiling shall be fixed on suitable hangers supported from structural ceiling.

All surface conduits shall be run in a vertical or horizontal direction. Diagonal runs shall not be permitted.

2.9.7. Penetration in Walls

Where proprietary cable transits are required, they shall be installed strictly in accordance with the manufacturer's recommended procedures. Where cables pass through walls, floors, or fire partitions, sleeves shall be installed to facilitate installation and subsequent withdrawal of the cable.

After installation of the cables, the hole(s) through which the cables pass shall be sealed with fire resisting material to achieve the fire rating as the structure through which they pass. Details of the proposed sealing method shall be submitted for approval prior to implementation. Cables passing through external walls shall additionally be sealed with appropriate additional weather protection to prevent the ingress of water.

The fire resisting material shall intumesce to form a hard char that tightly seals penetrations against flame spread, smoke and toxic fumes. The fire resisting material shall be tested according to ASTM E119, ASTM E814 and ASTM E84. Test certification and test report shall be submitted.

The materials shall not emit toxic gases on exposure to fire. The materials shall be easy to dismantle and replace in case of rearrangement and also withstand vibration due to rail operation and seismic tremor.

2.9.8. Fixing of Conduit Fittings and Accessories

For concealed conduiting work, the fittings and accessories shall be completely embedded in walls/ceilings leaving top surface flush with finished wall/ceiling surface in a workman like manner.

Loop earthing wire shall be connected to a screwed earth stead inside outlet boxes to make an effective contact with the metal body.

2.9.9. Painting and Colour Coding of Conduits

Surface conduits shall be provided with 20 mm wide and 100 mm long color coding strips as below.

USE	COLOUR CODE
Low Voltage	Grey
Telephone	Black
Earthing System	Green
Security Conduit	Blue
Fire Alarm Conduit	Red
Control System Lighting	Purple

Conduit identification shall be provided by means of conduit feeder schedule. The conduit schedule shall identify all feeder conduits to be installed, using symbols and annotations. Conduits that are to be enclose circuits installed by other contractors shall be clearly indicated. Installation specification shall require pull wire and permanent tagging of each conduit access.

Conduit feeder schedule shall include the following information:

a) Conduit identification- Conduit Size

b) Circuit identification- Conduit Type

c) Conduit from- Conductor Description

d) Conduit to- Conductor Quantity

e) Identification of multiple runs

f) Drawing reference

2.9.10. Protection of Conduit

To safeguard against filling up with mortar / plaster etc. all the outlet and switch boxes shall be provided with temporary covers and plugs, which shall be replaced by sheet/plate covers as required. All screwed and socketed joints shall be made fully water tight with white lead paste.

2.9.11. Cleaning of Conduit Runs

The entire conduit system including outlets and boxes shall be thoroughly cleaned after completion of erection and before drawing in of cables. For cast in-situ conduits, it shall be checked for freedom from blockage and continuity as soon as the shuttering is removed. All conduit shall be swabbed through before wiring is commenced and cables hall not be drawn into any section of the system until all conduits and draw boxes for that particular section are fixed in position. The contractor shall submit for approval the ‘Method Statement including Tests’ to ensure the above requirements of cleaning of conduit runs.

2.9.12. Loop Earthing

Loop earthing shall be provided by means of insulated stranded copper conductor wires of sizes as per bill of quantities laid along with wiring inside conduits for all wiring outlets and sub mains. Earthing terminals shall be provided inside all switch boxes, outlet boxes and draw boxes etc.To satisfy requirements for earth fault loop impedance, the layout of conduit, trunking and ducting and routing of cables, contractor shall ensure that the maximum circuit lengths allowable are not exceeded.

3. Additional Requirements

a) All conduits shall be electrically and mechanically continuous and substantially water tight after installation. Electrical continuity and resistance of steel conduit systems intended to be encased in concrete shall be tested immediately prior to pouring.

b) Where an exposed galvanized surface has been cut or otherwise damaged, it shall be repaired by application of a zinc rich epoxy primer with a generous overlap on the existing sound metal coating. Exposed threads and connections shall be similarly treated. The epoxy primer shall be used strictly in accordance with the manufacturer’s instructions.

c) The use of inspection elbows and tees shall be avoided, as there is insufficient room for drawing in cables and, in addition the installation presents a shoddy appearance. Round boxes in accordance with relevant Indian Standards may be used. For conduits up to 25 mm diameter, the small circular boxes should be used. Circular boxes are not suitable for conduits larger than 32 mm, and for these larger sizes rectangular boxes should be used to suit the size of cables to be installed.

d) All circular boxes shall be provided with long spouts, internally threaded, incorporating a shoulder for the proper butting of the conduit.

e) An indelible display shall identify the cables laid along with the conduits at each conduit junction/ termination etc. for identification during any future handling.

f) The contractor shall submit ‘Method Statement’ for Installation, Testing and Commissioning of the conduit system as per the requirements of this specification. The ‘Method Statement’ shall also cover the aspect of quality and safety during Installation, Testing and Commissioning of the system.

g) For underground stations, switches shall be single pole and rated not less than 20A, for use on AC systems, including fluorescent or inductive loads.

h) All boxes and conduit accessories shall be fully weatherproof when used in outdoor locations and tunnels. Weatherproof boxes and conduit accessories shall also be used in locations other than outdoors where specified.

i) Covers for external application shall have machined faces, and shall be provided with neoprene type gaskets. No box shall be fixed in such a position as to be inaccessible on the completion of the building structure or other services.

4. Safety

The conduit system shall follow the relevant clauses of Central Electricity Authority (Measures relating to Safety and Electricity Supply) Regulations, 2010, National Building Code, 2005 and National Electrical Code, 2011 for the safety precautions to be adopted. In addition to this, following conditions should be adhered to:

a) All conduits shall be kept clear of gas and water pipes. In particulars, conduits shall be at least 150mm away from gas pipe. Where proximity to these pipes is unavoidable, they shall be effectually segregated e.g. using rubber or other insulating material to prevent appreciable voltage difference at possible points of contact. Segregation from extra low voltage circuits and telecommunication circuits shall also apply unless these are wired to that same voltage requirement as lighting and power circuits.

b) Emergency power sockets for Fire Services Department shall be provided in headwall units, tail-wall units and other locations shown on the drawings. The socket outlet shall be 32A, three phase, 5 pin socket outlets, in red colour, to IP54.

c) The materials used in the conduit system shall be fire retardant, shall not emit toxic gases and smoke on exposure to fire. The materials shall be easy to dismantle and replace in case of rearrangement and also withstand vibration due to rail operation and seismic tremor.

d) No timber or inflammable material shall be used for any supports.

e) No sharp edges or portion shall be present which may cause injury during handling or installation.

5. Energy Efficiency- NA

6. Maintenance and Life

This is an installation not requiring any maintenance with a long life. The contractor shall take suitable measures during manufacturing and installation of the product to achieve long life.

7. Special Condition- NA

8. Inspection, Testing & Dispatch

8.1. Inspection & Testing

All tests to be conducted as per relevant IS. In case of any contradiction with the relevant IS and this specification, this specification shall prevail.

8.2. Packaging and Sealing

The contractor shall ensure to the satisfaction of the Engineer-in- Charge that the material is properly packaged with inspection seal before dispatch. The contractor shall ensure satisfactory dispatch of material so as not to damage the packing condition and inspection seal.

Section A18: LOCAL ELECTRICAL PANELS – NOT USED

Section A19: Motors

TABLE OF CONTENTS

A19.1 General

A19.1.1 This Section specifies the manufacture and installation of motors.

A19.1.2 Unless otherwise specified or approved, all motors shall be of the totally enclosed fan-cooled type with Class F insulation. Motors for fire services pumps shall be of class H insulation and of IP 55 construction. Motors for fire rated operation shall be designed for continuous operation in an air stream temperature of 250°C for not less than two hour and shall be totally enclosed squirrel cage induction, fan cooled guarded to IP55 with Class H insulation. Insulation materials shall be suitable for the climatic conditions available in the city. Particulars of all motors shall be submitted for Approval.Motors shall be with IE2 Class.

A19.1.3 Motors shall be adequately rated to meet the service demands of associated driven units under all conditions and as limited by electrical and mechanical protective devices. The cooling fan of the motor shall be aluminium and protected by a metal fan cover.

A19.1.4 The type, design and manufacture of all motors shall be subject to Approval. Motors powered by AC shall comply with IS / IEC 60034 and shall be of squirrel cage, induction type. Voltage for motors shall be 415V 3-phase or 240V 1-phase, as required. Motors rated 0.37kW and larger shall be rated 415V, 3-phase, 50Hz. Motors rated smaller than 0.37 kW shall be operated at 240V 1-phase. Starters for motors shall include individual unit control transformers. Direct-on-line motor starters shall be used for motors up to and including 3.75 kW at 415 volts, 3 phase. All motors over this limit shall be equipped with reduced voltage starters of the star delta or autotransformer, two-step, closed transition type.

A19.1.5 The starting current shall not exceed 6 times of the full load current when direct-on-line starting at full voltage is applied.

A19.1.6 All motors shall be capable of accelerating the driven plant from standstill to rated speed with a terminal voltage of 80% of the nominal supply voltage at 50Hz in less than 4 seconds. All motors shall be capable of operating continuously or, for short-time rated motors, for the duration of the short-time period, at rated torque at any supply voltage between 90% and 110% of the nominal supply voltage at 50Hz. They shall be capable of delivering the rated torque when running at 70% of the nominal voltage for a period of 10 seconds without injurious overheating and under these conditions the slip shall not exceed 10%.

A19.1.7 All motors shall be capable of operating continuously without injurious effect and capable of driving the driven units at their rated output at any frequency between 48Hz and 52Hz together with any voltage between 90% and 110% of the nominal voltage.

A19.1.8 Vertically mounted motor shafts shall be supported by Approved thrust bearings.

A19.1.9 All bare steel internal parts except bearings shall be painted unless otherwise protected against corrosion.

A19.1.10 Motors shall be designed for low shaft current and shall have adequate provision to prevent bearing damage by shaft current.

A19.1.11 Not used

A19.1.12 An auxiliary marshalling box, electrically and mechanically separated from the power supply terminal boxes, shall be securely mounted on the motor frame for marshalling all small wiring for motor control or monitoring.

A19.1.13 For axial fans, external copper grease leads shall be provided for lubrication of motor bearings unless totally sealed bearings are used.

A19.1.14 The maximum motor efficiency shall be at the normal operating condition. Motors in all cases shall be entirely suitable for the duty intended. A margin of not less than 5% for compressors, 15% for fans and 10% for water pumps shall be provided for equipment over the continuous rating of the motor (without over-loading) under the normal operating condition unless otherwise specified. The motor shall have efficiency class IE2.

A19.1.15 The power factor of motors shall not be less than 0.85 lagging at the operating condition. Otherwise suitable power factor correction facilities shall be provided to improve the power factor. For two-speed fans, the requirement shall be achieved at both high speed and low speed operating condition.

A19.1.16 All steel works, supporting brackets and members, which are required for the pump motor installation, shall be hot-dipped galvanized to IS 4759. Motors shall be factory-painted to the appropriate finish. The paint used shall be capable of withstanding continuous operation in an air stream temperature of 250°C for not less than two hours without emitting smoke or toxic fumes.

A19.1.17 unless otherwise specification in this M&W Specified, in normal ambient conditions bearings shall be designed for 40,000 hours operating service (L10 life, Anti-Friction Bearing Manufacturer's Association) and provided with a grease outlet connection for in service lubrication. Grease fittings shall be brought to outside of fan housing and provided with covers which shall effectively exclude water and dirt. Grease outlet is not required if totally sealed type bearings are used.

A19.1.18 Motor terminals shall preferably be of the stud type, totally enclosed both from atmosphere and from the motor winding and be fully insulated from the frame. Rubber insulation shall not be used for connections between the windings and the terminals.

A19.1.19 Each motor terminal box shall be fitted with sealing chamber, conduit gland or adaptor plate, as required, together with the necessary fittings to suit the cable entry. Terminal markings and rating plates shall be provided. The terminal box shall be large enough for the specified cable sizes of the respective motor.

A19.2 Standards

A19.2.1 **Reference Codes and Standards**

A19.2.1.1 IS / IEC 60034 – for design, performance and efficiency of motors

A19.2.1.2 IS 1271 / IEC 60085 / NEMA – For insulation class rating

A19.3 Technical and Installation Requirements

A19.3.1 Motors of intake and exhaust fans of the axial type taking in 100% outside air shall be suitable for operation in atmosphere of up to 95% RH.

A19.3.2 Noise level shall meet IEC/BS EN 60034-9.

A19.3.3 The degree of protection of the motors shall conform to IP55 20 with the following additional requirements:

A19.3.3.1 Motor frames shall be steel or aluminium alloy or cast iron for motors inside station areas as appropriate.

A19.3.3.2 Motor frames shall be cast iron for motors in tunnels and Ancillary Buildings.

A19.3.3.3 Earthing terminal shall be provided.

A19.3.3.4 Unless otherwise specified, red oxide zinc chromate primer with two finish coats of grey paint shall be painted.

A19.3.3.5 All motors shall be squirrel type and shall be suitable for DOL or reduced voltage starting as specified on the Equipment Schedules and/or Drawings.

A19.3.4 Termination boxes of adequate size shall be die cast aluminium alloy or cast iron diagonally split type and suitably gasketed to prevent ingress of moisture and dirt with the following additional requirements:

A19.3.4.1 Rotatable in any of the four 90^{o} positions;

A19.3.4.2 Threaded holes suitable for mounting brass cable glands;

A19.3.4.3 Stud type terminals for terminating electric cables as specified; and

A19.3.4.4 Internal wiring connections to the main terminal boxes and auxiliary marshalling boxes.

A19.3.5 Bearings shall be double shields and have the following additional requirements:

A19.3.5.1 Ball or roller bearings with grease fittings and minimum pressure relief fittings for in service lubrication. Totally enclosed type bearings are also acceptable.

A19.3.5.2 Guide and thrust bearings for vertical motor drive units shall be subject to Approval.

A19.3.6 Lifting eyes shall be provided for motors.

A19.3.7 Tests shall be carried out before shipment to demonstrate that the equipment complies fully with specified requirements. Test certificates shall be provided for Approval.

A19.3.8 Not Used

A19.3.11 **Installation**

A19.3.11.1 Motors shall be installed as required by the driven equipment.

A19.3.11.2 Lifting equipment shall be provided for the installation of motors.

A19.3.11.3 Any additional steel works, supporting brackets and members which are required for the motors installation shall be provided by the Contractor at no extra cost to the Employer.

A19.3.11.4 The frames and supports shall be accurately set and leveled.

A19.3.11.5 Each motor shall be provided with an emergency stop push button at the Approved location. For outdoor installation, all emergency stop push buttons shall be of weatherproof type.

A19.3.11.6 All moving or rotating parts of motors, which can be accessed by personnel, shall be properly covered by steel wire mesh guards.

Section A20: SUB-MAINS ELECTRICAL SWITCH BOARDS AND EQUIPMENT – NOT USED

SECTION A21WATER TREATMENT SYSTEM

A.21 Water Treatment System

A 21.1 General Requirements

A 21.1.1 The precise form of water treatment at station shall depend on analysis of the particular borehole water supply.

A 21.1.2 Water treatment for the water circulating systems shall be provided to control corrosion and algae. Chemical cleaning of the systems shall comply with the requirements of the BSRIA application guide.

A 21.2 Water treatment for Chilled water systems

A 21.2.1 This method shall be included for by the contractor as the basic form of treatment for re-circulated chilled water circuits. The minimum provisions are as follows –

a) **Pre-cleaning and flushing out operation –**

- The entire chilled water shall be flushed out using appropriate chemical dispersant, detergent and defoamer of type and strength recommended by a reputable chemical water treatment manufacturer and guaranteed in writing by that company as suitable in every respect for the application in question.
- The chemical shall remain in the system for 72 hours including a minimum of 24 hours with pumped circulation in operation, unless otherwise recommended by supplier with free technical support accepted by the contractor.
- The system shall then be completely drained and flushed until tests at all drain points show that traces of suspended matter have been substantially removed to the contractor's approval.
- The system water shall be completely drained as rapidly as possible and contractor shall provide temporary 50 mm valved drain outlets on all points where the main pipe works is 50 mm or over, for this purpose.
- Subsequent to the flushing out operations the large drain down points shall be reduced to 15 mm valves or cocks or the sizes as indicated on the drawings. The system shall be refilled and flushed as necessary to achieve the required water quality level.

b) **Chemical Treatment to prevent corrosion, Scaling and Sludge Formation**

- Water treatment systems shall be provided by a water treatment specialist firm properly established and regularly engaged in the supply, installation, maintenance, administration and monitoring of water conditioning equipment and program to control corrosion, scale and sludge.
- Water treatment systems shall be in place and fully commissioned to operate at start-up of the air conditioning plant.
- Chemicals used for water conditioning and the methods to store and feed the chemicals shall comply with local by laws and applicable regulations.
- The agent shall be a liquid chemicals such as molybdate or a nitrite based agent blended with corrosion inhibitor that can provide such protection to the metal of closed circuit pipelines, system and equipment.

- Where applicable storage tanks shall be fabricated from glass reinforced plastics (grp) or material as specified.
- Chemicals used for the water conditioning shall have no detrimental effect on non-metallic materials such as elastomeric or plastic products used in the system. Chemicals shall be low toxicity, non flammable, suitable for the application and the system operating conditions.
- Where applicable chemicals shall be injected into the system by means of flexible plastic piping and injector fitting.
- Overall corrosion rate shall not exceed 5 μm per year for steel components of the circuit in continuous contact with the conditioned water.
- The contractor shall provide suitable comparative corrosion test coupons representing the metals in the treated circuit(s) for the purpose of measuring overall corrosion and pitting rates.
- Formation of adherent mineral deposits in the form of scale that cannot be flushed from heat transfer surfaces shall be prevented.
- Motor shall be provided along with the dosing tank. The motor shall on/off as per low level switch installed in the tank.

Treated water with TDS less than 2500 ppm, Turbidity less than 5 ppm and Total hardness less than 50 ppm shall be supplied to chilled water line. The water for the chilled water system shall be maintained at the following specification.

pH value	8.0-10.0
Total Dissolved Solids	below 2500 ppm
Total Hardness (as $CaCO_3$)	below 50 ppm
Turbidity (FTU scale)	below 5 ppm
Iron (increment)	below 1.0 ppm
Copper (increment)	below 0.2 ppm
Nitrite (NO_2)	above 250 ppm

A 21.3 **Water treatment for Condenser water systems**

A 21.3.1 This method shall be included for by the contractor as the basis form of treatment for water re-circulated between cooling tower and condenser applications. The minimum provisions are as follows –

a) **Pre-cleaning and flushing out operation –**

- The entire cooling tower/cooling water shall be flushed out using appropriate chemical dispersant, detergent and defoamer of type and strength recommended by a reputable chemical water treatment manufacturer and guaranteed in writing by that company as suitable in every respect for the application in question.
- The chemical shall remain in the system for 72 hours including a minimum of 24 hours with pumped circulation in operation, unless otherwise recommended by supplier with free technical support accepted by the contractor.
- The system shall then be completely drained and flushed until tests at all drain points show that traces of suspended matter have been substantially removed to the contractor's approval.
- The system water shall be completely drained as rapidly as possible and contractor shall provide temporary 50 mm valved drain outlets on all points where the main pipe works is 50 mm or over, for this purpose.

- Subsequent to the flushing out operations the large drain down points shall be reduced to 15 mm valves or cocks or the sizes as indicated on the drawings. The system shall be refilled and flushed as necessary to achieve the required water quality level.

b) **Chemical Treatment to prevent corrosion, Scaling and Sludge Formation**

- Water treatment systems shall be provided by a water treatment specialist firm properly established and regularly engaged in the supply, installation, maintenance, administration and monitoring of water conditioning equipment and program to control corrosion, scale and sludge.
- Water treatment systems shall be in place and fully commissioned to operate at start-up of the air conditioning plant.
- Chemicals used for water conditioning and the methods to store and feed the chemicals shall comply with local by laws and applicable regulations. The chemical agent employed shall be a combination of chemicals that will provide corrosion protection, scaling and microbiological inhibition to the metal pipelines and the construction material within condenser and cooling towers.
- The chemical agent shall be a non-flammable liquid chemical such as molybdate ar a phosphate-based agent blended with anti-foulant and amine based biocide. The agent shall b guaranteed by the chemical manufacturer as suitable in every respect for the application. Chemicals used for the water conditioning shall have no detrimental effect on non-metallic materials, such as elastomeric or plastic products used in the system.
- Storage tanks shall be fabricated from glass reinforced plastics (grp) or material as specified.
- Dosing and metering pumps shall inject into the system by means of flexible plastic piping and an injector fitting.
- The water treatment program shall provide corrosion control for the water circuit(s) by use of suitable corrosion inhibitors and pH control.
- Overall corrosion rate shall not exceed 5 μm per year for steel components of the circuit in continuous contact with the conditioned water.
- The contractor shall provide suitable comparative corrosion test coupons representing the metals in the treated circuit(s) for the purpose of measuring overall corrosion and pitting rates.
- Formation of adherent mineral deposits in the form of scale that cannot be flushed from heat transfer surfaces shall be prevented.
- A continuous bleed-off shall be specified for the cooling tower circuits.
- Internal chemical treatment of water in the circuit and external treatment of the make-up water shall be provided when bleed-off alone is inadequate to prevent scale formation, or if bleed-off is uneconomical because of excessive use of corrosion inhibitors.
- The electrical conductivity of the re-circulated water shall be used to control the cycles of concentration and chemical feed.
- Algae growth shall be prevented by using suitable algicides. Algaecides that may cause damage to equipment or impair operation shall not be used.
- Chemicals shall be fed to circuits requiring continuous make-up by automatic proportional feeding devices.
- Bleed off shall be automatic type
- Acid feeders, when used, shall be controlled by electronic pH controllers.

- Motor shall be provided along with the dosing tank. The motor shall on/off as per low level switch installed in the tank.
- pH value 8.0-10.0
- Alkanality below 2000 ppm
- Total Dissolved Solids below 2500 ppm
- Total Hardness (as $CaCO_3$) below 50 ppm
- Turbidity (FTU scale) below 5 ppm
- Iron (increment) below 1.0 ppm
- Copper (increment) below 0.2 ppm
- Nitrite (NO_2) above 250 ppm

A 21. 4 **Water testing equipment**

Unless otherwise specified in the particular technical specification water testing equipment corresponding to the type of water treatment system and chemical used shall be provided to monitor and verify the performance of the water treatment system offered and shall be handed over by the contractor's operation and maintenance staff.

The equipment shall be of portable type suitable for field sampling and testing. For pH value testing, pH meters or phenol red solution and color discs shall be provided. Other relevant test kits shall include total dissolved solids and corrosion inhibitor level testers.

A 21.5 **Training operation and maintenance facilities**

No matter which type of water treatment system is offered adequate on site operational training and demonstration of the water treatment system shall be provide for the principal's operation and maintenance staff prior to hand over of the system or after completion of installation. It shall include but not be limited to the following –

i. Familiarisation of equipment and system including the function of each dosing chemical.

ii. Water treatment equipment set up/ adjustment instructions.
iii. On site training of water sampling and testing, equipment and system operation and maintenance procedure.
iv Precautions required for handling the chemicals and remedial actions required following a spillage.

A competent person from the approved water treatment specialist and equipment suppliers shall hold on-site training, which shall last for at least two months period with one full day in-hand training per month.

The contractor shall provide prominent warning notices, goggles, gloves and necessary accessories for handling the chemicals.

A sufficient number of sampling points in the pipe work or equipment for water analysis, routine inspection and testing shall be provided.

A21.6 The contractor shall provide the chemical volume based on system water volume and considering 10% wastage

SECTION A.22 Intake & Extract Louvers

A 22.1 General Requirements

A 22.1.1 Intake & Extract louvers shall be provided as shown on the drawings/BOQ. These shall be made of GSS frame and blades in extruded aluminum construction.

A 22.1.2 Blades shall be inclined at 45 degree and placed at a pitch of 75mm to minimize water ingress. The assembly shall be complete with bird wire guard of galvanized steel. Face velocity shall not be more than 2.5m/sec with corresponding pressure drop of 19 Pa.

A 22.1.3 Galvanized M.S channel (Box channel) of 100X50mm shall be provided to support grid of not more than 1500 X 1500mm. GSS frame of louvers shall be 1.6mm and blades shall be 1.5mm thick.

A.22.1.4 The louvers shall be powder coated as per colour scheme approved by engineer in-charge. Depth of louvers shall be 150mm.

Specification of FRP Louvers

STANDARD CONSTRUCTION

FRAME
4" x 1.06" x .125" (107 x 27 x 3.2) thick Series, 625 Vinyl Ester Resin fiberglass channel.

BLADES
0.125" (3.2) thick fiberglass at 45°blade angle, approximately 5" (127) center to center.

SCREEN
PVC coated bird screen .50" (13) mesh 19,gage (1.1) is standard. Fiberglass insect, screen, 18-16 mesh.

MAXIMUM TEMPERATURE
200°F.

MINIMUM SIZE
12"w x 12" h (305 x 305).

MAXIMUM SIZE
Single Section – 72" wide x 72" high (1829 x1829).
Multiple Section Assembly – Unlimited.
In factory assembly size is 90" wide x 144" high (2286 x 3658).

APPLICATION
Stationary louver for corrosive environments.Components are assembled with epoxy and/or,monel fasteners.

ACCESSORIES
Shall include:
• Extended sill.
• Exterior coatings.

SECTION A.23

Clean Agent Based flooding system

The cubicles shall be protected against fire by means of an ‘automatic fire detector and extinguisher system’, ‘Fire trace’ type or equivalent, complete with Clean Agent Container, approved by Chief Controller of Explosives, valve, flexible detection and delivery system in the form of a flexible tube made of special polymer, capable of withstanding a normal pressure of 12 bar and a maximum pressure of 20 bar, suitably routed inside the panel for detection of fire. The Clean Agent container shall be suitably mounted on the panel and shall be capable of flooding the cubicle with Clean Agent, within the shortest response time, not more than 10 seconds after the fire is sensed by the flexible detector tube. The contractor shall submit the complete technical data of the system to the Employer, for approval.

SECTION A.24 – VARIABLE FREQUENCY DRIVES

VARIABLE FREQUENCY DRIVES FOR HVAC SYSTEMS

24.1 GENERAL REQUIREMENTS

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

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

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

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

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

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

g. All wiring in the VFD panel shall be of LSZH type.

24.2 TECHNICAL REQUIREMENTS

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

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

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

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

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

24.2.4 The VFD shall have a dual 5% impedance DC link reactor (harmonic filters) on the positive and negative rails of the DC bus to minimize power line harmonics and protect the VFD from power line transients. The chokes shall be non-saturating. Swinging chokes that do not provide full harmonic filtering throughout the entire load range are not acceptable.

24.2.5 VFDs with saturating (non-linear) DC link reactors shall require an additional 3% AC line reactor to provide acceptable harmonic performance at full load, where harmonic performance is most critical.

IEEE519, 1992 recommendations shall be used for the basis of calculation of total harmonic distortion (THD) at the point of common coupling (PCC). On request VFD manufacturer shall provide THD figures for the total connected load. The contractor shall provide details of supply transformer rating, impedance, short circuit current, short circuit impedance etc to allow this calculation to be made.

24.2.6 All VFDs shall contain integral EMC Filters to attenuate Radio Frequency Interference conducted to the AC power line. The VFDs shall comply with the emission and immunity requirements of IEC 61800-3 : 2004, Category C1 with 50m motor cable (unrestricted distribution). The suppliers of VFDs shall include additional EMC filters if required to meet compliance to this requirement.

24.2.7 The VFD's full load output current rating shall meet or exceed the normal rated currents of standard IEC induction motors. The VFD shall be able to provide full rated output current continuously, 110% of rated current for 60 seconds and 120% of rated torque for up to 0.5 second while starting.

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

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

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

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

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

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

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

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

24.3 PROTECTIVE FEATURES

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

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

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

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

24.3.5 VFD shall include current sensors on all three output phases to accurately measure motor current, protect the VFD from output short circuits, output ground faults, and act as a motor overload. If an output phase loss is detected, the VFD will trip off and identify which of the output phases is low or lost.

24.3.6 If the temperature of the VFD's heat sink rises to 80°C, the VFD shall automatically reduce its carrier frequency to reduce the heat sink temperature. It shall also be possible to program the VFD so that it reduces its output current limit value if the VFD's temperature becomes too high.

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

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

24.3.9 Protect from output switching : The VFD shall be fully protected from switching a contactor / isolator at the output with out causing tripping e.g.: for switching on/off the isolators of the AHU / ventilation fans / pumps near the motor with VFD in ON mode.

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

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

24.4 INTERFACE FEATURES

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

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

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

24.4.4 Password protected keypad with alphanumeric, graphical, backlit display can be remotely mounted. Two levels of password protection shall be provided to guard against unauthorized parameter changes.

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

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

24.4.7 Display shall be programmable to communicate in multiple languages including English, Chinese, Korean, Japanese, Thai and Indonesian.

24.4.8 A red FAULT light, a yellow WARNING light and a green POWER-ON light shall be provided. These indications shall be visible both on the keypad and on the VFD when the keypad is removed.

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

24.4.10 A three-feedback PID controller to control the speed of the VFD shall be standard.

24.4.11 This controller shall accept up to three feedback signals. It shall be programmable to compare the feedback signals to a common setpoint or to individual setpoints and to automatically select either the maximum or minimum deviating signal as the controlling signal. It shall also be possible to calculate the controlling feedback signal as the average of all feedback signals or the difference between a pair of feedback signals.

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

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

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

24.4.15 The VFD shall have three additional PID controllers which can be used to control damper and valve positioners in the system and to provide setpoint reset.

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

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

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

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

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

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

24.4.22 Standard Control and Monitoring Inputs and Outputs

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

b. Two terminals shall be programmable to act as either as digital outputs or additional digital inputs.

c. Two programmable relay outputs, Form C 240 V AC, 2 A, shall be provided for remote indication of VFD status.

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

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

f. Each shall be independently selectable to be used with either an analog voltage or current signal.

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

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

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

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

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

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

24.4.23 Optional Control and Monitoring Inputs and Outputs

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

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

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

d. Modules may include such items as:

e. Additional digital outputs, including relay outputs

f. Additional digital inputs

g. Additional analog outputs

h. Additional analog inputs, including Ni or Pt temperature sensor inputs

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

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

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

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

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

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

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

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

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

i. The VFD shall include a sequential logic controller to provide advanced control interface capabilities. This shall include:

ii. Comparators for comparing VFD analog values to programmed trigger values

iii. Logic operators to combine up to three logic expressions using Boolean algebra

iv. Delay timers

v. A 20-step programmable structure

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

24.5 SERIAL COMMUNICATIONS

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

Metasys N2
Modbus RTU

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

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

24.6 ADJUSTMENTS

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

24.6.2 Four independent setups shall be provided.

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

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

Each setup shall be programmable for a unique current limit value. If the output current from the VFD reaches this value, any further attempt to increase the current produced by the VFD will cause the VFD to reduce its output frequency to reduce the load on the VFD. If desired, it shall be possible to program a timer which will cause the VFD to trip off after a programmed time period.

If the VFD trips on one of the following conditions, the VFD shall be programmable for automatic or manual reset: external interlock, under-voltage, over-voltage, current limit, over temperature, and VFD overload.

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

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

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

24.7 OPTIONAL FEATURES

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

24.8 SERVICE CONDITIONS

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

24.8.2 -10 to 45°C for ratings upto 90 kW without derating

24.8.2 -10 to 40°C for ratings 110 kW and higher without derating

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

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

24.8.5 AC line voltage variation :$\pm$ 10% of nominal with full output.

24.8.6 VFD Enclosure protection : IP 55, integral, with no additional cabinets.

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

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

24.8.9 All VFDs shall be plenum rated.

24.9 QUALITY ASSURANCE

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

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

SECTION A.25 CHILLER PLANT MANAGER

Chiller Plant Manager

General

A. The Chiller Plant Optimizer system shall be as indicated on the drawings and described in the specifications.

B. Network Automation/Control Engine and Direct Digital Control (DDC) technology shall be used to provide the functions necessary for control of mechanical systems on this project.

C. The control system shall accommodate simultaneous multiple user operation. Access to the control system data should be limited only by operator password. Multiple users shall have access to all valid system data. An operator shall be able to log onto any work-station on the control system and have access to all appropriate data. The system shall be fully web enabled as shown on the drawings and as specified in this specification.

D. The control system shall be designed such that each mechanical system will be able to operate under stand-alone control. As such, in the event of a network communication failure, or the loss of any other controller, the control system shall continue to independently operate under control.

E. Communication between the control panels and all work-stations shall be over a high speed TCP/IP network. All nodes on this network shall be peers. The operator shall not have to know the panel identifier or location to view or control an object. Application Specific Controllers shall be constantly scanned by the network controllers to update point information and alarm information.

F. The equipment to be monitored and controlled include the following:

   a. Control of Chillers with Primary, Secondary Chilled Water Pumps, Condenser Water Pumps ,Cooling Towers and Motorized Butterfly Valves.
   b. Measurement and monitoring of the chilled water temperatures and flows.
   c. IkW/TR measurement of each chiller.
   d. Energy metering using special Energy Software with dashboard and customized reporting tools for DMRC stations.
   e. Automatic Alarm routing through e-mail and SMS to user

Worl Included

A. Provide a Chiller Plant Optimizer incorporating Network Automation/Control Engine and Direct Digital Control (DDC), equipment monitoring, and control; Advanced DDC Controllers (DDCs) interfacing directly with sensors, actuators and environmental delivery systems (i.e. chilled water distribution, etc) and mechanical devices for all items indicated on drawings described herein including motorized butterfly valves, VFDs, panels; a primary communication network to allow data exchange from DDCto DDC; terminal equipment, DDC Controllers interfacing with sensors, actuators, terminal equipment devices; a secondary BACnet MS/TPcommunication network interfacing DDCs to network automation controllers ; hardware and software interfaces to third-party control equipment.

B. The Chiller Plant Optimizer System (CPO) shall be a state of the art technology, freely expandable for any future expansion plans. The system (CPO) shall have a minimum controlling capacity of 10,000 physical points without upgrading the data server software or related hardware. In general the system shall support “Open Architecture Concept” with capability to Dynamic Data Exchange (DDE) Link. The system shall be modular in nature, and shall permit expansion of both capacity and functionality through the addition of sensors, actuators, controllers and operator devices, while re-using existing controls equipment.

The CPO as provided shall incorporate, at minimum, the following integrated features, functions and services:

1. Operator information, alarm management and control functions.
2. Enterprise-level information and control access.
3. Information management including monitoring, transmission, archiving, retrieval, and reporting functions.
4. Seamless integration of third party system protocol such a MODbus-RTU, BACnet IP
5. Diagnostic monitoring and reporting of CPO functions.
6. Offsite monitoring and management access.
7. Energy management / Reports / Dashboards

CPO System Architecture

The system architecture shall be as follows:

The Chiller Plant Optimizer (CPO) shall use an open architecture and fully support a multi-vendor environment. To accomplish this effectively, the CPO shall support open communication protocol standards and integrate a wide variety of third-party devices and applications. The system shall be designed for use on the Internet, or intranets using off the shelf, industry standard technology compatible with other owner provided networks.

The system shall be designed into three tiers and contain a field tier (the tier that contains all of the field level controllers, and application specific controllers), an automation tier (this is the tier that connects all of the field tiers), and an enterprise tier (this is the tier that connects all of the automation tiers). No two-tier design is acceptable.

The CPO shall consist of the following hardware and software:

1. Standalone Network Automation/Control Engine(s)
2. DDC Field Equipment Controller(s) and Input/Output Module(s)
3. Workstation and Energy Management Software

1. Standalone Network Automation/Control Engine

A. Controller shall provide supervisory control over the control network and shall support all three (3) of the following communication protocols:
1. BACnet Standard MS/TP Bus Protocol ASHRAE SSPC-135, Clause 9
2. The NAE shall be BACnet Testing Labs (BTL) certified and carry the BTL Label.
3. The NAE shall be tested and certified as a BACnet Building Controller (B-BC).

B. Control networks shall provide either "Peer-to-Peer," Master-Slave, or Supervised Token Passing communications.

C. A BACnet Protocol Implementation Conformance Statement (PICS) shall be provided for each controller device (master or slave) that will communicate on the BACnet MS/TP Bus.

D. Network engine shall have Unlimited number of user license without any additional cost of license on the OWS.

E. Network engine shall be able to access by 4 simultaneous user.

F. Network engine shall l be browsed by Microsoft Internet Explorer and Netscape Navigator

G. Network engine processor should be of 32 bit configuration

H. Network engine should have inbuilt display and keys to operate in absence of PC

I. Network engine should have inbuilt IO points , functionally able to act as a DDC controller as well as a Supervisory controller.

J. Network engine should support AHARAE standard BACnet MS/TP protocol , Proprietary Protocol shall not be accepted

K. Network engine should support integration of third party protocol (eg MODbus-RTU) seamlessly without adding additional hardware

L. For BACnet MS/TP or IP integration, the Network engine should be support auto discovery to discover the field devices and field points

M. Network engine should support DHCP function for IP addressing

2. Workstation and Energy Management Software(To be integrated with station BMS)

The specifications mentioned herein are applicable for the energy management system which is to be provided in the station BMS and OCC for central monitoring.

A. The system shall provide a real-time database incorporating data from analog, logical or pulse inputs.

B. It should be support up to 1000 TCP/IP addresses for the supervisory controllers in the Enterprise network

C. Historian of point data shall be configurable as part of the point definition. Historian shall be provided for both snapshots and averages with intervals ranging from 5 seconds to 24 hours

D. Trend and change of value data shall be stored within the engine and uploaded to a dedicated trend database or exported in a selectable data format via a provided data export utility

E. The system shall provide a configurable data storage subsystem for the collection of historical data. Data can be stored in SQL database format

F. The system shall be able to store all the events

G. The operator interface shall be flexible in its connection to the CPO server. Both serial wireless, 3G and LAN connection shall be possible. The operator interface shall provide standard dial-up modem support. Using other packages such as Microsoft Terminal to make the modem connection shall not be acceptable.

H. CPO management level software shall have Unlimited number of user license without any additional cost of license on the OWS.

I. CPO software shall be web based software shall allow 5 simultaneous user access.

J. Server software shall be able to browsed by Microsoft Internet Explorer and Netscape Navigator

K. Energy Management software capable of fetching the energy data from the BMS and store the data into separate application database (SQL) for analysis. This Software should have the following Key features:

- SEGMENTATION OF ENERGY INFORMATION AT A GLANCE.
- CUSTOMISABLE ENERGY DASH-BOARD.
- ENERGY REPORT GENERATION AGAINST SELECTION OF TIME AND FREQUENCY.
- CO2 EMISSION CALCULATION AND REPORTING.
- WEB BASED TOOL. NO ADDITIONAL SOFTWARE REQUIRED.
- Automatic Alarm EMAIL / SMS OPTION AVAILABLE

L. The software shall have Ready Access Portal Architecture , graphics and management software shall be accessible thru smart phones.

M. A minimum of 100 unique passwords shall be supported. Provide a minimum of 100 categories of systems to which individual operators may be assigned.

N. Monthly calendars shall be provided that allow for simplified scheduling of holidays and special days for a minimum of 5 years in advance.

O. Alarms shall be routed directly from Network Automation Engines to PCs and servers. It shall be possible for specific alarms from specific points to be routed to specific PCs and servers.

P. The system shall provide flexible trending allowing real-time, historical or archived data to be trended in a variety of formats. In addition, trend data types shall be able to be combined to allow for comparisons between data e.g. current real-time data versus archived data

Q. The system shall support a flexible reporting package to allow easy generation of report data. The reports provided should include pre-configured standard reports for common requirements such as Alarm Event reports and custom report generation

R. The system shall provide up to six levels of security providing varying degrees of access to system operation and configuration functions.

3. DDC Field Equipment Controller(s) and Input/Output Module(s)

A. General purpose DDC controllers shall be minimum 32 bit microprocessor based with FLASH base of operating system.

B. The devices shall be programmable and capable of extensive measuring, control and monitoring functions.

C. All DDCs shall support modular architecture with the following:
 1. A CPU with Power Supply Module
 2. Distributed I/O modules to accommodate Input/Output points.

D. Energy management programs such as optimum start/stop, load reset, duty
cycling, night purge, distributed demand control and others must be resident on each DDC.

E. As a back up, DDC's shall store DDC programs and data files on non-volatile EEPROM or flash memory to allow simple and reliable additions and changes. Each DDC shall have a 72 hours battery backed real-time clock.

F. Each panel shall be provided with a socket for a Portable Operators Terminal (POT) which can be connected via Bluetooth communication for easy access for testing & trouble shooting and no need to open the panel, and a port for network communications In max. speed of 76Kbps

The DDC I/O modules should communication within the CPO network by ASHARE BACnet MS/TP protocol, no other proprietary protocol is accepted protocol

H. All the DDC should be BTL listed.

I. DDC shall support PRAC and PID logic

J. The DDC software configuration tool shall use be GUI based logics

Immersion Temperature Sensors:

a. Immersion sensors shall be provided with a separable stainless steel/brass well. Pressure rating of well is to be consistent with the system pressure in which it is to be installed.

b. Operating range shall be -20 to 70 deg C; pressure rating shall be min. PN 16, IP 54 protection, 1000 ohms platinum at 0 deg. C, . To meet UL 1995 plenum requirements if necessary. Accuracy to ±0.73F° at 70°F (±0.41C° at 21°C), DIN Class B

c. Standard of Acceptance: Johnson Controls TE-6300 series or approved equal.

Outside Air Temperature Sensors:

Chilled Water Flow Meters:

1. Flow meter shall be a single paddle/ electro-magnetic / insertion flow meter.
2. The wetted material shall be constructed of stainless steel or brass
3. Provide output to CPO.
4. Install flow meters according to manufacturer's instructions paying particular attention to the upstream and downstream piping requirements.
5. Standard of Acceptance: Kele/ABB/Sanitech

Local Control Panels:

1. The control panel should be lockable and IP 55 rating
2. Standard of Acceptance: BCH

PART 3 Executions

The CPO shall be designed, installed, and commissioned in a turnkey operational manner; including all labour not noted in Work by others paragraph of PART I of this section of these specifications, and not noted in other sections of these

DATA SHEET FOR CHILLER PLANT MANAGER	
Unit Type	DDC Type
List of Equipments:	
No of Water cooled chillers	As per BOQ
N of Air cooled chillers	As per BOQ
No of Primary Chilled water pumps	As per BOQ
No of Secondary Chilled water Pumps	As per BOQ
No of Condenser water Pumps	As per BOQ
No of Cooling towers	As per BOQ

Control:	
DDC / IOM CONTROLLERS for equipment control	32 bit, UL Listed BACnet (BTL certified)
Supervisory controller	32 bit, UL Listed BACnet (BTL certified)
Supervisory controller features	A) The Network supervisory Controller shall have imbedded graphic capability for generating web based user graphics and support Multi user with simultaneous minimum 5 user login facility B) Unlimited user without additional license (C) Shall be browsed by Microsoft Internet Explorer and Netscape Navigator (D) BTL certified (E) Web engine should be 32bit configuration (F) Should have inbuilt display and keys to operate in absence of PC (G) Should have desired inbuilt IO points (H)Functionally able to act as a DDC controller also apart from Supervisory controller function (I) Web engine should support AHARAE standard BACnet MS/TP protocol , Proprietry Protocol shall not be accepted (J) Web engine should support integration of third party protocol (eg MODbus-RTU) seamlessly without adding additional hardware (K) Web engine should support DHCP function for IP addressing

SECTION A.26 Electronic Anti fouling system

A.26.1 The electronic anti fouling system shall prevent the scale fouling by including dissolved minerals ions to precipitate into larger particles by the use of square wave current source. Which shall be supplied along with this equipment.Which shall be wrapped around condenser water circuit.

Control Box
Electrical Input 110-240v AC , 50-60 Hz
Enlosure NEMA 12

Soleniod coil

Pipe size as per BOQ of different stations for condenser water system
Enclosure ABS Plastic weather resistant.

TVS SPECIFICATION

TABLE OF CONTENT

Section V00: General Specification for Tunnel Ventilation System

TABLE OF CONTENT

V00.1 Purpose and Scope

V00.1.1. This Specification describes the minimum standards of the Tunnel Ventilation System (TVS).

V00.1.2. The Works to be executed under the Contract include the manufacture, verification, delivery, installation, testing, commissioning and technical support for a complete, integrated Tunnel Ventilation System, including all control centres, fans, dampers, ducts, necessary to deliver the requirements of this Specification.

V00.1.3. The Tunnel Ventilation System is to be manufactured, supplied, installed, tested and commissioned by the Contractor and shall meet all performance and functional requirements as defined in the Specification.

V00.2 Codes and Standards

V00.2.1. Unless otherwise stated, the safety and environmental control system design shall be governed by all applicable local codes, regulations and standards.

V00.2.2. In addition to local requirements, environmental control system designs shall also comply with the following codes of practice, standards, specifications and manuals.

V00.2.3. Local codes, regulations and standards shall take precedence where these standards or requirements are more onerous than other international standards.

V00.2.4. NFPA 130: 2010 - Fixed Guideway Transit Systems: any non-compliance shall be approved in writing by the DMRC.

V00.2.5. British Standards or other internationally recognised standards as approved by the Employer's Representative.

V00.2.6. Ventilation and air conditioning systems for stations and tunnels are to be based on the current "Handbook" series published by the American Society of Heating, Refrigeration and Air Conditioning and the "Subway Environmental Design Handbook" published under the sponsorship of the United States Department of Transportation, Urban Mass Transportation Administration.

V00.2.7. Fans shall be rated in accordance with the "Standard Test Code for Air Moving Services" and the "Test Code for Sound Rating Air Moving Devices" of the Air Moving and Conditioning Association Inc., USA.

V00.2.8. Noise criteria shall be as described herein and in the current four volume "Handbook" series published by the American Society of Heating, Refrigeration and Air Conditioning Employer’s Representatives (ASHRAE).

V00.2.9. The standards to be followed during construction, and installation of the Tunnel Ventilation System shall be generally as listed, except where specific requirements are given in the Specification, which shall take precedence. The Contractor may propose alternative or additional standards for review by the Employer’s Representative at least 60 days before application.

V00.2.10. All codes and standards shall be submitted in English language. The design of any one system shall be to a single code or specification. The parallel use of different codes for particular items or components shall not be allowed.

V00.2.11. International Standards

<u>Anti-Friction Bearings Manufacturers Association (AFBMA).</u>

9, Load Ratings and Fatigue Life for Ball Bearings.

11, Load Ratings and Fatigue Life for Roller Bearings.

Air Moving and Control Association (AMCA):

210, Laboratory Methods of Testing Fans for Rating.

300 Test Code for Sound Rating of Air Moving Devices

301 Method for Publishing Sound Ratings

American National Standards Institute (ANSI):

S12.34 Survey Methods for Determination of Sound Power Levels of Noise Sources.

B46.1 Surface Texture, Surface Roughness, Waviness and Lay, Part 1.

C1 Specification of General Requirements of a Quality Program

S12.36 Survey Methods for Determination of Sound Power Levels of Noise Sources

Z49.1 Safety in Welding and Cutting

Z55.1 Grey Finishes for Industrial Apparatus and Equipment

American Welding Society (AWS):

D1.1, Structural Welding Code - Steel.

D1.3, Structural Welding Code - Sheet Steel.

American Society for Testing and Materials (ASTM):

A 36 Structural Steel

A 123, Zinc (Hot Galvanised) Coatings on Products Fabricated from Rolled, Pressed and Forged Steel Shapes, Plates, Bars, and Strip.

A 193 Alloy-Steel and Stainless Steel bolting Materials for High-Temperature Service

A 194 Carbon and Alloy Steel Nuts for Bolts for High-Pressure and High-Temperature Service

A 239, Locating the Thinnest Spot in Zinc (Galvanised) Coating on Iron or Steel Articles by the Preece Test (Copper Sulfate Dip).

A 276 Stainless and Heat-Resisting Steel Bars and Shapes

A 525, Steel Sheet, Zinc Coated (Hot Galvanised) by the Hot-Dip Process.

A 588, High Strength Low Alloy Structural Steel with 50 ksi (345 MPa) Minimum Yield Point to 4 Inch (100 mm) Thick.

A 666 Authentic Stainless Steel, Sheet, Strip, Plate, and Flat Bar for Structural Applications

B 247, Certification for Aluminium Alloy Die Forgings, Hand Forgings and Rolled Ring Footing.

B 686, Aluminium Alloy Castings, High Strength

E 84 Surface Burning Characteristics of Building Materials

E 94, Radiographic Testing.

E 138, Wet Magnetic Particle Inspection.

E 155, Reference Radiographs for Inspection of Aluminium and Magnesium Castings.

Institute of Electrical and Electronic Employer’s Representatives (IEEE):

85 Standard Test Procedure for Airborne Sound Measurements on Rotating Electric Machinery

112, Test Procedure for Polyphase Induction Motors and Generators.

519, Recommended Practices and Requirements for Harmonic Control in Electric Power Systems.

Military Specifications (Mil. Spec.):

MIL-P-24441/A, General Specification for (Ships), Paint, Epoxy Polyamide.

MIL-P-24441/1A, Paint, Epoxy Polyamide, Green Primer, Formula 150, Type 1.

MIL-P-24441/2A, Paint, Epoxy Polyamide, Exterior Top Coat, Haze Grey, Formula 151, Type 1.

DOD-P-21035A Paint, High Zinc-Dust Content, Galvanising Repair (Metric)

National Electrical Manufacturer's Association (NEMA):

ICS-1, General Standards for Industrial Control and Systems.

ICS-1.1, Safety Guidelines for the Application, Installation and Maintenance of Solid-State Control.

ICS-2, Industrial Control Devices, Controllers and Assemblies.

ICS-3, Industrial Systems.

MG-1, Motors and Generators.

MG1-12.54 Efficiency

Steel Structures Painting Council (SSPC):

PA-1, No. 1 Shop, Field and Maintenance Painting.

PA-2, Method for Measurement of Dry Paint Thickness with Magnetic Gauges.

SP-1, Solvent Cleaning.

SP-2, Hand Tool Cleaning.

SP-3, Power Tool Cleaning.

SP-6 Commercial Blast Cleaning

SP-10, Near White Blast Cleaning.

PA-1 Shop, Field, and Maintenance and Painting

PA-2 Method for Measurement of Dry Paint Thickness with Magnetic Gauge

International Standards Organisation (ISO):

ISO 281 Rolling bearings: dynamic load ratings and rating life

ISO 1680 Test code for the measurement of airborne noise emitted by rotating electrical machinery: engineering method for free field conditions over a reflecting plane

ISO 5135 Noise: Air distribution and diffusion

ISO 8821 Mechanical vibration: balance. Balancing shaft and fitment key convention

ISO 117 Method of testing the performance of jet fans

Underwriter's Laboratories, Inc. (UL):

508, Industrial Control Equipment.

International Electrotechnical Committee (IEC)

IEC 34-1 Rotating electrical machines: rating and performance

IEC 34-5 Rotating electrical machines: classification of degrees of protection provided by enclosures of rotating electrical machines

IEC 34-6 Rotating electrical machines: methods of cooling (except traction engine)

IEC 34-7 Rotating electrical machines: classification of types of constructions and mounting arrangements (except traction engine)

IEC 34-8 Rotating electrical machines: Terminal markings and direction of rotation

IEC 34-9 Rotating electrical machines: noise limits

IEC 34-14 Rotating electrical machines: mechanical vibration of certain machines with shaft heights 56mm and higher. Measurement, evaluation and limits of vibration.

IEC 85 Thermal evaluation and classification of electrical insulation

IEC 892 Effects of unbalanced voltages on the performance of three phase cage induction motors

V00.3 Work Included in the Services

V00.3.1. The Services to be performed by the Contractor shall include, but not be limited to, the following:

1. Manufacture, delivery, system assurance, installation, testing and commissioning of the TVS
2. Technical supports for operation and maintenance of the TVS
3. Supports for training
4. Training of the Employer’s engineers and training instructors, operations staff, maintenance staff and engineering staff
5. Decommissioning, removal and/or disposal of temporary works
6. Prototyping and prototype testing
7. Manpower and all necessary tools for work execution and installation commissioning

8. Warranty period after commissioning

V00.3.2. In a general manner, all works, facilities and services to ensure a perfect and complete execution of works under this scope and according to relevant code and standards and to this Specification.

V00.4 Scope of the work of supply

V00.4.1. The Contractor shall supply all equipment and facilities necessary to meet the requirements of this technical specification, including, but not limited to:

1. Control equipment, including accessories / components,
2. Tunnel ventilation fans and Trackway Exhaust Fans including motors and terminal boxes.
3. Tunnel ventilation system dampers (TSVD) and Air Nozzles;
4. Tunnel booster fans
5. All auxiliary equipment such as: conical fan inlets and outlets, sound attenuators, ducts, inspection covers & access doors;
6. All cables and cabling necessary for the Works;
7. Enclosures and supporting brackets for housing and fixing equipment;
8. Power supply and distribution panel, circuit breakers, and isolators;
9. All equipment associated with any interfaces required to ensure operation within the performance requirements;
10. All special test equipment and tools, including data configuration tools;
11. maintenance tools;
12. All equipment necessary to carry out factory and on site testing and commissioning;
13. Compressed Air System including copper piping and solenoid valves to operate pneumatically operated TVS Dampers (TVSD);
14. Minor civil works like grouting of equipment, cutting and finishing good openings in brick walls;
15. Any other equipment/material requited for the satisfactory completion of work;
16. All software, appropriately safety validated, verified and certified, to meet the requirements of the Specification;
17. All software and hardware required for data logging.

V00.5 Control and monitoring

V00.5.1. Control and monitoring facilities

V00.5.1.1. Equipment involved in safety shall be controlled locally by means of dual redundant programmable logic controllers (PLCs) with local intelligence able to play scenarios controlled either at central level or at station level.

V00.5.1.2. For security reasons, equipment shall also be controlled locally in manual mode with hard-wired controls

V00.5.1.3. The Contractor shall provide necessary hardware, software and data, so that the control and monitoring functions for the TVS can be performed.

V00.5.1.4. The Contractor shall provide control sequencing to provide safety of equipment and passengers during emergency situations and especially during evacuation of passengers.

V00.5.1.5. The TVS shall be completed and **equipped with provision** for automatic, manual, local and remote controls so that the fans and motors can be operated from a Station Control Room (SCR) or from the Operations Control Centre (OCC).

V00.5.1.6. The three following controls levels shall be available:

V00.5.1.7. Direct control: to control equipment in case of control system failure. This control level is ensured by hard-wired control panel close to the equipment.

V00.5.1.8. Local control: in the station, a terminal shall be configured to control operations of the station and tunnel emergency equipment. This terminal shall be able top control smoke extraction scenarios.

V00.5.1.9. Central control: Control of TVS equipment shall be also possible via the SCADA.

V00.5.1.10. The priority of control levels shall be as follows: direct control shall supersede local control which itself shall supersede central control.

V00.5.1.11. The programmable logic controllers that will control emergency equipment shall be together, which will be provided by others.

V00.5.1.12. Temperature monitors will be installed by the Contractor in the tunnel at a suitable distance away from the station.

~~V00.5.1.13.~~ Not Applicable

V00.5.2. Manufacturer's qualification

V00.5.2.1. The TVS equipment shall be furnished by manufacturers who have manufactured similar equipment for a period of at least five years.

V00.5.2.2. Control equipment shall be installed, tested, commissioned and adjusted under the direct supervision of the manufacturer or his authorised agent.

V00.5.2.3. Installation of TVS Equipment shall be by experienced personnel under the direct supervision of trained and qualified contractor's personnel and Certified by representative of Manufacturer for the Installation as per quality standard of the manufacturer.

V00.5.2.4. All items necessary to make the installation complete in every respect, safe and ready for regular operation and use, and for easy maintenance shall be furnished by the Contractor.

V00.5.2.5. In design and purchase of equipment, the interchangeability of items, subassemblies, parts, motors, starters, relays, and transducers shall be considered.

V00.6. Verification, testing and commissioning

V00.6.1. General requirements

V00.6.1.1. The Contractor shall put in place a full testing regime to demonstrate that all the requirements of the Specifications are met.

V00.6.1.2. All the tests shall be carried out by the Contractor or by an external laboratory which shall be previously submitted to the Employer's approval. The Employer's Representative reserves the right to carry out any additional tests he considers necessary to satisfy himself that the system meets the requirements of the Specification.

V00.6.1.3. The Contractor shall support the Employer's Representative additional tests as necessary. The Contractor's support shall include, but not limited to:

1. Provision of test equipment
2. Attendance of competent staff
3. Provision of test procedure

V00.6.1.4. The Contractor shall submit a testing and commissioning program for the Employer's Representative

V00.6.1.5. The Contractor shall provide all test equipment (measuring set-up and measurement devices) and staff to perform tests as required per relevant standards.

V00.6.1.6. Calibration certificates shall be provided for each measurement devices

V00.6.1.7. Before performing the tests, the Contractor shall submit to the Employer's approval a detailed test methodology.

V00.6.1.8. Tests shall allow to assess the whole installation. The Contractor shall provide synthetic notes showing complete results from the tests.

V00.6.1.9. It will not be allowed to deduce from any calculations a parameter that can be determined by measurement.

V00.6.2. Factory tests

V00.6.2.1. Contractor shall perform factory tests including but not limited to:

1. Materials

   Contractor shall provide certificate of material tests

   Checking of particular conditions applied to materials and especially their properties according to this Specification and Standards

2. Components

   Checking of their conformity to drawings

   Checking of right execution of the anti-corrosion protection

3. Motors

   Measurement of heating

   Measurement of efficiency

   Measurement of the Cos phi

4. Fans

   Measurement of airflow, static and total pressures, efficiency and noise generation

5. Dampers

   Testing of leakage performance

Testing of structural integrity

Testing of time of operation

6. Air Compressor Airflow, Pressure test Automatic operation
7. For all the mechanical components

Checking of welding quality

Checking of right execution of the anti-corrosion protection

8. Electrical panels

Checking of the overall right operation of components

Checking of the right execution of logical functions to be realised

V00.6.3. On-site tests

V00.6.3.1. Contractor shall perform on-site tests including but not limited to:

1. Measurement of airflow and power at fans motors for the whole TVS at operation condition.
2. Measurement of airflow inside the tunnel.
3. Sound power level measurement at 1m backward of each shaft grate
4. Noise measurement at different points in the measurement plan
5. Inside, sound power level measurement at 1.2m height from the floor and at a minimum distance of 1m from all ducts.
6. Vibration measurements at different points of the concrete slab of TVS plant room. Measurement along a vertical axis. Measurement device bandwidth to be linear between 10Hz and 100Hz. Slope of the response curve to be 20dB per octave minimum.
7. Operation tests and work commissioning; testing of all manual and automatic commands, failure simulations and overall checking of the right operation of mechanical and electrical systems.
8. Testing of TVS Dampers and Pneumatic system.

V00.6.4. Tests on Completion

V00. 6.4.1. On completion of the testing given in the specifications, it will be the responsibility of the contractor to restore the Tunnel Ventilation System to full operational use following System Acceptance Tests (SAT).

V00. 6.4.2. During SAT, all interfaces with external Systems to the TVS shall be tested. Tests on completion shall be necessary tests to demonstrate that the system meets the performance requirements specified.

Section V01: Tunnel Ventilation System – Fan Units

TABLE OF CONTENT

V01.1. General

V01.1.1. This Attachment specifies the requirements for furnishing tunnel ventilation fan units and appurtenances as specified herein. Fans shall be the product of a single manufacturer whose name shall appear on the fan motor unit and, who shall have previously furnished emergency fan motor units to other rail transit agencies for minimum Five years.Thetrackway exhaust fans, those connected to the underplatform and overtrack exhaust ducts, are not reversible fans.

V01.2. Quality control

V01.2.1. Reference Standards

V01.2.1.1. Anti-Friction Bearings Manufacturers Association (AFBMA)/ISO281

9, Load Ratings and Fatigue Life for Ball Bearings.

11, Load Ratings and Fatigue Life for Roller Bearings.

V01.2.1.2. Air Moving and Control Association (AMCA)

210, Laboratory Methods of Testing Fans for Rating.

V01.2.1.3. American National Standards Institute (ANSI)

S12.34, Survey Methods for Determination of Sound Power Levels of Noise Sources.

V01.2.1.4. American Welding Society (AWS)

D1.1, Structural Welding Code - Steel.

D1.3, Structural Welding Code - Sheet Steel.

V01.2.1.5. American Society for Testing and Materials (ASTM)

A 123, Zinc (Hot Galvanised) Coatings on Products Fabricated from Rolled, Pressed and Forged Steel Shapes, Plates, Bars, and Strip.

A 239, Locating the Thinnest Spot in Zinc (Galvanised) Coating on Iron or Steel Articles by the Preece Test (Copper Sulfate Dip).

A 525, Steel Sheet, Zinc Coated (Hot Galvanised) by the Hot-Dip Process.

A 588, High Strength Low Alloy Structural Steel with 345 MPa Minimum Yield Point to 100 mm thick.

B 247, Certification for Aluminium Alloy Die Forgings, Hand Forgings and Rolled Ring Footing.

B 686, Aluminium Alloy Castings, High Strength

E 94, Radiographic Testing.

E 138, Wet Magnetic Particle Inspection.

E 155, Reference Radiographs for Inspection of Aluminium and Magnesium Castings.

V01.2.1.6. Institute of Electrical and Electronic Employer’s Representatives (IEEE)

112, Test Procedure for Polyphase Induction Motors and Generators.

519, Recommended Practices and Requirements for Harmonic Control in Electric Power Systems.

V01.2.1.7. Not Used

V01.2.1.8. International electro technical association (IEC).

V01.2.1.9. Steel Structures Painting Council (SSPC)

PA-1, No. 1 Shop, Field and Maintenance Painting.

PA-2, Method for Measurement of Dry Paint Thickness with Magnetic Gauges.

SP-1, Solvent Cleaning.

SP-2, Hand Tool Cleaning.

SP-3, Power Tool Cleaning.

SP-10, Near White Blast Cleaning.

V01.2.1.10. Underwriter's Laboratories, Inc. (UL)

508, Industrial Control Equipment.

V01.2.2. Manufacturer's Qualifications

V01.2.2.1. The fan manufacturer shall show at least Five years of continuous and current experience in the design, assembly, and testing of axial flow tunnel ventilating fans and experience in the design and fabrication of units capable of operating in 250 degrees C air stream for two hour.

V01.2.3. Submittals

V01.2.3.1. Before providing the fan manufacturer with Notice to Proceed the Contractor shall submit to the Employer's Representative for his review and consent, evidence of the manufacturer's qualifications including, but not limited to the following data:

1. Theoretical fan-motor composite performance curves for equipment proposed to be furnished under this Contract.

- ❖ Fan-motor unit performance curves from shut-off to free delivery shall have the following data plotted as ordinates versus airflow rate, in cubic meters per second, as abscissa:
  1) Total pressure, Pascals.
  2) Static pressure, Pascals.
  3) Total efficiency, percent.
  4) Static efficiency, percent.
  5) Kilowatt input to fan impeller.
  6) Kilowatt input to the motor.
- ❖ Separate curves shall be furnished for forward and reverse direction. Each curve shall be identified.
- ❖ The system resistance curve shall be plotted on each curve. The point of operation shall be indicated.
- ❖ In addition, furnish the following data:
  - – Theoretical performance curves for each rotational direction shall be plotted for fan motor units for the following blade pitch angles:
  1) Maximum blade pitch angle.
  2) Minimum blade pitch angle.

3) Design blade pitch angle.

4) A minimum of two intermediate pitch angles between maximum and minimum blade pitch angle other than design pitch angle.

– These performance curves shall be plotted with abscissa as cubic meters per second and ordinates as:

1) Total pressure, in Pascals.

2) Kilowatt input to fan impeller.

– Acceleration time for each rotational direction from standstill to operating revolutions per minute. Plot operating revolutions per minute as abscissa and acceleration time as ordinate.

– The fan load torque curve at operating speed. Plot percent revolutions per minute as abscissa and percent full load torque as ordinate.

❖ All performance curves shall be plotted to such scales as will make it possible to read the data accurately.

❖ The following information shall be imprinted on each performance curve.

- Project title.
- Contractor's name.
- Name and address of fan manufacturer.
- Authority's fan designation number.
- Fan speed in revolutions per minute.
- Volume of air delivered in cubic meters per second.
- Fan static pressure in Pascals.
- Fan total pressure in Pascals.
- Fan outlet velocity pressure in Pascals.
- Fan outlet velocity in meters per second.
- Fan static efficiency in percent.
- Fan total efficiency in percent.
- Fan-motor unit total efficiency in percent.
- Kilowatt input to fan impeller.
- Kilowatt input to motor.
- Air density in kilograms per cubic meter
- Fan housing diameter in millimetres.
- Fan outlet area in cubic meter.
- Fan rotor hub diameter in millimetres.
- number of fan blades.
- Direction of airflow (forward or reverse).

- Design blade pitch angle.
- Rotational moment of inertia of fan rotor assembly in kilograms per square meter.
- Maximum acceleration time required to start fan-motor unit from rest and accelerate it to operating speed, in seconds.

2. Theoretical fan motor performance curves shall cover the entire range of load conditions from no load to 115 percent of full load.

❖ Composite curve for each size of motor plotted with abscissa as kilowatt output and ordinates as:

- Current in amperes.
- Speed in revolutions per minute.
- Efficiency in percent.
- Power factor in percent.
- Torque in Nm.

❖ Composite curve for each size of motor plotted with abscissa as speed in revolutions per minute and ordinates as:

- Motor current in amperes.
- Motor torque in Nm.
- Fan torque in Nm.
- Motor acceleration from standstill to synchronous speed in seconds.

❖ The current versus speed and torque versus speed curves for each size of motor shall indicate the current and torque from standstill to the synchronous speed of motors.

❖ Temperature Test: Time in minutes as abscissa versus temperature rise in degrees C as ordinates when operated at full voltage and speed.

❖ Insulation Resistance-Temperature Test: Test result values shall be plotted on semi-logarithmic graphs, the insulation resistance values as logarithmic ordinates and the temperature values as uniform abscissa.

❖ Also, for comparison purposes, a curve indicating the safe operating value of insulation resistance shall be plotted on the same sheet with the insulation resistance temperature test curve.

❖ The following information shall be stated on each motor performance curve and data sheet:

- Project title.
- Contractor's name and address.
- Name and address of motor manufacturer.
- Authority's fan designation number in which the motor forms a part.
- Motor type.
- Motor serial number.

- Motor frame size.
- Motor nameplate kilowatt rating.
- Electrical characteristics (voltage-phase-frequency).
- Full load and no load current in amperes.
- Direction of rotation of motor.
- Speed in revolutions per minute.
- Service factor.
- Rotational moment of inertia of rotor in kilograms per square meter.
- Electrical characteristics of space heater, including voltage and kilowatt input.

❖ Fan sound power levels in decibels shall be submitted as hereinafter specified. For reversible fans for both directions of airflow. Sound power levels in the eight frequency bands at design airflow capacity shall not exceed the listed values on the fan schedule shown at each octave band.

❖ Manufacturer's quality assurance program.

❖ A complete list of projects on which similar fans for rail or transit tunnel projects have been applied. List shall include:

- Name of owner or user.
- Contract number(s).
- Original installation date(s).
- Current condition of equipment.
- A list of all known failures for the past ten years, including their apparent causes, corrective work effected (including design changes), and a description of equipment service and operating conditions.

❖ List of components proposed to be purchased from other manufacturers, giving name of manufacturer, type and characteristic of each item and applicable .

V01.2.3.2. Within 45 days after issue of a Notice from the Employer’s Representative, the Contractor shall submit the following for the Employer’s Representative review and consent.

1. Certified shop drawings for fans, motors, fan-motor unit bases, installation drawings, installation instructions, dimensioned drawings for anchor bolt locations, and any additional data required to demonstrate compliance with Contract documents.
2. Certificate of Compliance signifying that equipment to be furnished under this Contract meets the requirements specified herein and for the fan inlet conditions shown on the drawings.
3. Shop drawings shall indicate weight of each component.
4. Data on motor bearing lubricant.
5. Factory and field-test procedures.

6. List of technical support items specified and list of any additional support items required.
7. Fan-motor unit disassembly and reassembly instructions.
8. Procedures for separately removing and replacing motor, rotor and blades, as well as procedures for removing a complete fan-motor unit without disassembly.

V01.2.3.3. Within 14 days after successful completion of tests specified herein and of any additional tests conducted at the Contractor's own option, Contractor shall submit the following:

1. Certified test results for all fan and motor factory tests conducted. All test data shall be bound in one report. The test report shall be indexed and cross-referenced in an easily understood manner.
2. All records and results of non-destructive examinations made at completion of each examination.
3. Field test results
4. Radiographic inspection films.

V01.3 Technical and installation requirements

V01.3.1. Description

V01.3.1.2. Fans shall be axial flow type with reversible operation. Emergency fan-motor units shall be required to operate in the forward or reverse direction of airflow, with a capability of starting, stopping, or reversing the direction of flow at any time. The trackway exhaust fans, those connected to the underplatform and overtrack exhaust ducts, are not reversible fans.

V01.3.1.3. Fan-motor units shall be direct-driven by internally mounted electric motors, with provision for manual adjustment of the pitch of the individual blades. Fan-motor units shall be statically and dynamically balanced and shall have non overloading characteristics.

V01.3.1.4. Motors shall be the product of a single manufacturer, whose name shall appear on the motor performance curves and other data submitted. The motors shall conform to all applicable ANSI, IEEE, ISO, IEC and NEMA. Motors shall not be provided with self-contained thermal protective devices.

V01.3.1.5. Motors shall be of the totally enclosed, air-over, cast iron or steel round frame, induction type, continuous duty, variable torque, and shall be flange, pad, or foot mounted.

V01.3.1.6. Nameplate kilowatt shall be actual continuous brake kilowatts developed without any consideration of the "air over" factor.

V01.3.2. Operating Environment

V01.3.2.1. Fans and all parts thereof shall be capable of withstanding the effect of all stresses and loads under starting, operating, and reversing conditions specified. Fans and all components shall be capable of operating for two hour in an ambient temperature of 250 degrees C. Fans, motors and components shall be capable of withstanding sudden temperature changes as a result of fire between the extremes of zero and plus 250 degrees C or vice versa in a time frame of 20 seconds. Contractor shall submit maximum design stress of rotating components at maximum fan speed and 250 degrees C Temperature and shall designate types of materials to be used in design by their ASTM designations or approved equal. Fan motor unit shall be capable of withstanding 250 degree Celsius for two hour.

V01.3.2.2. Fans shall be designed and built to serve an underground subway environment and to function under conditions of high humidity and high temperature and the inlet and outlet conditions indicated.

V01.3.3. Fan-Motor Unit Design Requirements

V01.3.3.1. Fan-motor unit performance shall be rated for the airflow and total pressure specified per the Contractors Drawings at a maximum air density of 1.2 kilograms per cubic meter.

V01.3.3.2. Fan performance curves for either direction shall rise continuously with decreasing flow between free delivery and 60 percent of free air delivery or to maximum kilowatt rating. Fans shall be capable of operating continuously at specified design points for forward and reverse flow.

V01.3.3.3. Emergency fan-motor units shall have a total efficiency of not less than 60 percent in forward flow and not less than 50 percent in reverse flow, when operating at the specified nominal flow rate.

V01.3.3.4. Fans shall be capable of starting from a standstill to full speed, in not more than 30 seconds as per NFPA 130, without failure of any part of the unit. Fans shall be capable of reversing to full speed from either direction of airflow and rotation during an emergency within 20 seconds, after a 10 second delay between power interruption and the energising of the motor for the reversed rotation, without failure of any part of the unit.

V01.3.3.5. Emergency fan performance, when operating in the reverse direction of airflow and against a constant equivalent orifice, shall not deviate by more than ten percent in airflow delivered from the fan-motor unit performance curves for operation in the forward direction of airflow at any point between 60 percent of the nominal airflow rate and free delivery.

V01.3.3.6. Brake kilowatts shall not exceed the nameplate kilowatts of the fans when operating in either direction of airflow.

V01.3.3.7. Pressure variations of plus or minus 300 Pa induced by external causes shall not result in movement of the fan operating point along the fan operating curve into the region of unstable operation. This requirement does not affect the kilowatt requirement for the design operating point.

V01.3.3.8. Fans shall not operate in stalling range of fan performance curve during parallel operation (forward or reverse direction).

V01.3.4. Fan fabrication

V01.3.4.1. Impeller hub and blades shall be of rating for 250 degreeC for 2 hours fabricated of aluminium alloy castings (ASTM B686) or forgings (ASTM B247) or steel (ASTM A-588, Grade A and A-151, 1020 hot rolled) or equivalent BS, EN, & DIN Std., suitable for the specified performance and environment. Fan rotating components shall be designed such that no measured or calculated stress level shall exceed 60 percent of the components materials yield strength at design temperature. Fan blades shall not vary in weight by more than 2 percent. Blades shall be manufactured of a homogeneous material as specified herein and shall have no cast-in or embedded materials of any kind. Individual blades shall be secured to the hub by not less than four bolts per blade, or shall be clamped securely between the two halves of a split hub or between suitably designed and manufactured clamp plates or by suitable number of studs. Blade bolts, hub bolts or clamp plate bolts shall be readily accessible. The pitch of the blades shall be manually adjustable without removing impeller from fan unit. (Pitch is defined as the angle formed by the chord line of a blade root cross-section and a line parallel to the direction of rotation.) The ratio of the hub diameter to the fan-housing diameter shall not be less than 0.35. The hub shall have index marks embossed or engraved to show the design operating blade setting and the blade settings for a minimum of five additional increments of stagger angle with not less than two on each side of design setting. In addition, the Contractor shall provide metal templates or other approved devices to facilitate settings of blade angles in the field. One template shall be provided for each type of fan for each station that is subject to the Authority's approval. One template shall also be provided with each maintenance manual.

V01.3.4.2. Emergency fan housings, including motor mounts and motor supports shall be fabricated of hot-rolled steel not less than 6 mm thick. Clearance between housing inner diameter and blade tips shall be sufficient to allow for thermal growth difference between blades and steel housing at temperature of 250 degrees C. Welds located in the air stream shall be ground smooth. Flanged rings shall be continuously welded to the outer periphery at each end of the housings, or flanges may be rolled as part of the housing. Provide remote lubrication fittings for lubrication of fan and motor bearings from easily accessible location.

V01.3.4.3. The rotor assembly shall be fastened to the motor shaft by means of an approved-keyed positive locking device. The rotor assembly shaft shall be an extension of the drive motor shaft. Rotor assembly fastening to shaft shall be designed to prevent looseness during temperature of 250 degree C.

V01.3.4.4. Motor mounts and motor supports shall be designed to support the entire weight of the impeller and the motor, and to maintain the alignment of the fan-motor unit assembly in the specified mounting position and to maintain vibration levels within the specified limits. Motor supports shall be sufficient in number to provide the required strength and rigidity and shall be continuously welded to the motor mount and to the housing. Fan motor and fan rotor assembly shall be totally enclosed within the fan housing and not protrude at either end of the fan housing.

V01.3.4.5. Nosepiece coverplates, access doors, hatch covers, and aerodynamic separation plates, where provided, shall be secured by means of positive fastening devices which are fully effective for both directions of impeller rotation, for all blade settings, and for all conditions of operation specified herein.

V01.3.4.6. Emergency fan-motor unit assembly supports shall be of carbon steel not less than 10 mm thick for TVF and 6mm thick for TEF. Supports for horizontally floor mounted fans shall include fan-motor unit structural steel base with vertical supports extending from the base to the fan housing centreline flange and with horizontal thrust plates extending over the full length of the fan housing. Vertical supports and thrust plates shall be welded continuously to the surfaces with which they come into contact.

V01.3.4.7. Contractor shall provide a 6-mm thick silicone gasket between all adjacent companion flanges; width of gasket shall be same as flange width. Gaskets shall be capable of withstanding an ambient temperature of 250-degree C for two hour without degradation of sealing ability and without emitting toxic or noxious fumes.

V01.3.4.8. Sufficient lifting eyes shall be provided on each fan assembly to facilitate on-site installation and removal of the fans.

V01.3.4.9. Bolts shall be not less than 12 mm diameter. Bolts, nuts, washers and lock washers used on the fans and components shall be Type 316 stainless steel, silicon bronze, or other corrosion-resistant material as approved.

V01.3.5. Shop finishes

V01.3.5.1. After fabrication and prior to assembly, all inside and outside surfaces of all fan housings, fan housing extensions, supports and fan-motor unit bases shall be prepared in conformity to the requirements of SP-10 New White Blast Cleaning and shall be given a rust-inhibiting coating, which may consist of an approved plastic coating, or bonderizing, or phosphatizing, followed by the application of a suitable rust-inhibiting primer and finish paint that is resistant to abrasion and to exposure to elevated temperatures. Surface finish shall be capable of withstanding for one hour in an ambient temperature of 250 degree C without degradation of its protective quality, and without emitting toxic or noxious fumes.

Contractor may also provide Hot dip Galvanised fan housings, fan housing extensions, supports and fan-motor unit basesetc with minimum of 275 GSM galvanisation.

V01.3.5.2. Surface finishes damaged during transport or assembly shall be restored to their original condition and colour by the installing Contractor.

V01.3.6. Motor components and construction

V01.3.6.1. The motors shall be designed for continuous operation for a period of at least two hour at a maximum ambient temperature of 250 degree C.

V01.3.6.2. Motors shall be equipped with factory installed resistance space heaters within the motor enclosure to prevent condensation of moisture in the motor windings. The heaters shall be energised whenever the motor is not in operation and shall be automatically de-energised whenever the motor is in operation. The heaters shall be provided with leads terminated in a terminal box external to the fan housing. Motor space heaters shall be energised within 24 hours of the time when the unit is installed at site.

V01.3.6.3. Nameplate kilowatt of the motors shall be as indicated. Kilowatt input required by the fans shall not exceed the nameplate kilowatt of the motors at any point on the fan performance curve in either direction of airflow. Motors shall have a minimum overall efficiency of 90.0 percent at the rated load. .

V01.3.6.4. Motors shall be capable, under the specified operating conditions, of accelerating the impeller from a standstill to rated rotational speed in not more than 15 seconds after being energised. Motors shall also be capable of decelerating the impeller and accelerating to rated rotational speed in the opposite direction in not more than 30 seconds after being energised for reverse rotation.

V01.3.6.5. Motors shall be rated in accordance with NEMA/IEC Standards for the locked rotor input (kilovolt-amperes per kilowatt) required to meet the specified acceleration performance. Motor and shaft shall be designed for full plug reversal. Motors shall have a minimum of Type H insulation and shall be rated for Class F temperature rise when tested at the service factor load as a minimum requirement. Motor service factor shall be 1.15.

V01.3.6.6. Motors shall be provided with a minimum of six (two per phase) Resistance Temperature Detectors (RTDs) / Positive Temperature Coefficient (PTC) and wired to a terminal box external to the fan housing for remote indication of excessive running temperature during normal operation. These wires shall be taped and terminated in the junction box. The electronics required to interpret the RTD / PTC signal and generate an alarm for each phase shall be included in the instrument panel.

V01.3.6.7. During continuous operation, motors shall be insensitive to line voltage variation of ten percent above or below the rated voltage and to normal frequency variation. Motors shall be able to accelerate to full speed at rated load with starting voltage (dip) of 25 percent below rated voltage of the motor.

V01.3.6.8. Not applicable.

V01.3.6.9. Minimum power factor of motors shall be 85 percent of the high speed winding at the rated load.

V01.3.6.10. The motor shall be designed for accelerating fan impeller from standstill to operating speed without exceeding the rated temperature rise.

V01.3.6.11. The motor shall be single winding. The starting and accelerating torque on motor windings shall be sufficient to permit the motor rotor and fan impeller to attain full winding speed without tripping the motor controller overload relays, which shall be set at a current corresponding to 140 percent of the motor full load current.

V01.3.7. Motor Materials and Components

V01.3.7.1. Motor shafts shall be steel, designed and constructed to support and drive the fan impeller under all specified operating conditions.

V01.3.7.2. Motor starters and controls shall be furnished by the electrical contractor.

V01.3.7.3. Each motor shall have at least two ball or roller type grease lubricated, electric motor grade, noise tested bearings selected for the specified operating conditions of the fan motor unit. The bearings shall have a minimum L-10 life rating of 40,000 hours as defined by the latest standards of the Anti-Friction Bearings Manufacturers Association (AFBMA)/ISO Standard.

V01.3.7.4. Grease lines shall be brought from each bearing to accessible fittings, external to the fan housing, at the ground floor level of the fan room. The lines shall be fabricated of stainless steel, copper or other corrosion resistant alloy, seamless metallic tubing. The tubing shall not be crushed or scored during installation and the lines shall have neither kinks nor sharp bends. Lines penetrating the housing shall be rigidly secured to the housings to prevent vibration of the lines and be provided with grommets. Grease supply lines shall terminate in straight lubrication fittings. Grease fittings shall only allow the proper amount of grease to each bearing. The bearing lubricant shall be capable of providing the lubrication properties specified by the bearing manufacturer under conditions of operation for two hour with the lubricant at a temperature of 250 degrees C.

V01.3.7.5. The motor leads shall be of cable, suitable for two hour at 250 degree C, wired to a gasketted NEMA 12 / ISO Standard terminal box mounted externally to the fan housing. The terminal box shall have screw type pressure terminals strips for terminating control wires, exterior mounting lugs, full cover gasket. , The dimensions of the terminal box to be coordinated with the space requirement for the termination of thesuitable size of cable.The terminal block should be suitable for termination of cables of suitable size. The conduit and terminal box shall be rigidly secured to the fan housing in a manner which will prevent vibration and air leakage and shall be capable of withstanding 250 degree C for two hour without causing fan failure. Terminal box shall be oriented to receive feeder conduits from any direction. Motor leads shall be installed to avoid interference with control leads and terminal strips. Sufficient cable slack shall be provided to permit testing of cables without disconnecting any connections. The terminal box shall be designed to take the cables of required sizes.

V01.3.7.6. Lifting lugs shall be provided on the exterior of motors.

V01.3.8. Nameplates

V01.3.8.1. Each fan shall be provided with a stainless steel nameplate permanently stamped with the name and address of the manufacturer, Contractor's identification number, fan type, Authority designated fan number, shop order, serial number of fan, year manufacturer, maximum safe operating speed of fan in revolutions per minute, fan impeller diameter, maximum design operating speed and corresponding volume of air delivered and the fan total pressures at density specified. The nameplate shall be securely screwed or riveted to the exterior of fan housing in a conspicuous position. The “material for the ~~J~~JMRC Project” should be inscribed on the Name Plate.

V01.3.8.2. Each motor shall be provided with two identical stainless steel nameplates permanently stamped with the name and address of the motor manufacturer, the motor kilowatt, voltage, phase, frequency, insulation type, full load current, locked rotor indicating code letter, minimum overall efficiency, the design temperature rise over ambient of the motor, type of duty, the terminal connection chart for the motor, rating of space heater, speed in revolutions per minute, service factor, motor type and serial number, bearing numbers and shop order number. One nameplate shall be furnished on the motor and the other either riveted or screwed on the exterior of the fan housing immediately adjacent to the fan nameplate.

V01.3.8.3. Each fan shall be provided with a 250 mm long by 40 mm wide metallic arrow that shall indicate the direction of forward airflow. The arrow shall be rigidly and permanently attached to the fan housing, in a position that can be readily viewed when the fan is in its final operating position. 20 mm letters shall be engraved on the arrow to read as follows: "EXHAUST".

V01.3.8.4. Each fan shall be provided with 200 mm long by 50 mm wide stainless steel plate permanently stamped with the labels "Grease Line Supply Port" and "Grease Line Exit Port".

V01.3.8.5. All the nameplates and the arrows shall be placed so as to be readily visible.

V01.3.9. Low pressure differential switches

V01.3.9.1. Fans shall be equipped with a low-pressure differential switch.

V01.3.9.2. Differential pressure switches shall be diaphragm operated with 100 mm diaphragm to actuate a single pole double throw snap switch. Motion of the diaphragm shall be restrained by a calibrated spring that can be adjusted to set the exact pressure differential at which the electrical switch will be actuated. Motion of the diaphragm shall be transmitted to the switch button by means of a direct mechanical linkage.

V01.3.9.3. Operating Range: Plus 1500Pa, zinc die casting and steel stamping; zinc plated for 200 hour salt spray resistance. Diaphragm shall be moulded silicone rubber. Calibration spring shall be stainless steel.

V01.3.10. Factory tests and inspections

V01.3.10.1. The Contractor shall perform factory tests as described below. The Authority's representatives may, at their option, witness any or all tests. Observations made during the tests and all test results shall be recorded in a document form, certified by the Contractor and submitted to the Authority for approval.

V01.3.10.2. The proposed test procedure shall be furnished to the Authority prior to the factory tests.

V01.3.10.3. . Each unit must satisfactorily pass all specified factory tests as described below under production fan tests.

V01.3.10.4. The test procedures specified herein shall be sequential in the order prescribed. Any fan type or size or component thereof which fails to satisfactorily perform any test as specified shall be considered unacceptable. Failing parts shall be replaced and the entire unit shall be retested as specified herein.

V01.3.10.5. Before manufacture is begun on any ventilation fan-motor unit to be furnished, Contractor shall submit full details of all test procedures, samples of all test report forms, and full details of the methods by which the raw test data has been calculated, to the Authority for approval.

V01.3.11. Motor Tests

V01.3.11.1. Motors shall be tested in accordance with the procedures specified in IEEE Publication 112 and NEMA MG-1/IEC-60034. A certified test report and certified performance curves verifying the theoretical motor performance curves for all of the co-ordinates specified shall be submitted to the Authority for approval. Performance curves for each type and size of fan motor shall be plotted to a scale that will facilitate accurate readings.

V01.3.11.2. One motor of each nameplate kilowatt rating and service factor shall be tested for forward and reverse modes as follows:

❖ Tests to obtain actual fan motor performance curves verifying the calculated fan motor performance curves submitted and other data specified hereinafter.

- Full load current in amperes
- No load current in amperes
- Full load input in kilowatts
- No load input in kilowatts
- Locked rotor current in amperes
- Locked rotor input in kilovolt amperes
- Locked rotor Nm.

❖ Tests to determine:

- – Winding resistance
- – Losses, no load and full load
- – Temperature rise
- ❖ Dielectric tests
- ❖ Visual bearing inspection

V01.3.11.3. The remaining motors shall be tested at its rated synchronous speed unwitnessed. Reversible motors shall be tested in one direction. Tests shall include the following:

- ❖ Winding resistance
- ❖ No load current in amperes
- ❖ Dielectric tests
- ❖ No load speed
- ❖ Visual bearing inspection
- ❖ Locked rotor current in amperes

V01.3.11.4. The following data shall be plotted for each direction as ordinates versus kilowatts as abscissas up to 115 percent full load:

- ❖ Current, in amperes
- ❖ Efficiency, in percentage
- ❖ Power factor, in percentage

V01.3.11.5. The following data shall be plotted for each motor frame size as ordinates versus revolutions per minute as abscissas:

- ❖ Current in amperes
- ❖ Torque in Nm
- ❖ Power factor in percentage

V01.3.11.6. The following information shall be imprinted on each motor performance graph:

- ❖ Project title
- ❖ Name of Contractor
- ❖ Name of motor manufacturer
- ❖ Catalogue name and number of motor
- ❖ Direction of rotation of motor
- ❖ Speed, in revolutions per minute
- ❖ Electrical characteristics (voltage/phase/frequency)
- ❖ Motor designation number
- ❖ Motor frame size
- ❖ Motor kilowatt rating
- ❖ Full load current
- ❖ Designation of the fan of which the motor forms a part

- ❖ Service factor
- ❖ Polar moment of inertia of the fan-motor unit, in meter-kilogram squared
- ❖ Electrical characteristics of space heater, including voltage and kilowatt input.

V01.3.11.7. Test data for the certified performance curves shall be recorded at the rated voltage and frequency of the motor, continuously over the speed range from standstill to rated rotational speed of the motor.

V01.3.12. Radiographic Inspection

V01.3.12.1. Provide a certification that, for all fan hubs and blades, x-rays shall be on aluminium part , with notation of the x-ray numbers, and also that zyglo testing / Coloured Dye Penetration Testing Shall be performed on steel part. In addition, provide a complete list of the identification numbers for all hubs and blades actually installed in each fan.

V01.3.12.2. Certification of visual acceptability, the x-ray procedure, the x-ray films, and proof of traceability of conformance with alloy specifications of the metal used to cast the hub and blades shall be submitted to the Authority for approval. The identification number of the x-ray film shall be etched on each blade and hub at a location that will not create adverse stress concentrations to reduce the design safety factor at the point of critical stress.

V01.3.13. Overspeed Tests

V01.3.13.1. At least one TEF and one TVF fan rotor assemblies manufactured and furnished for this Contract shall be subjected to an overspeed test at the factory as specified herein prior to assembly of the complete fan-motor units.

V01.3.13.2. After radiographic inspection and after static and dynamic balancing, each completely assembled fan impeller shall be spin tested in both directions. Spin testing of individual components, such as blades and rotors, in lieu of testing complete impellers, is not acceptable. Each fan impeller shall be spun at 125 percent of the maximum design operating speed for a period of not less than three minutes. Following each spin test, a visual inspection for surface defects shall be made by the Contractor. Certificates of visual acceptability shall be submitted to the Authority for approval.

V01.3.14. Vibration Test

V01.3.14.1. After assembly each fan-motor unit shall be checked for bearing operation in both directions of rotation. Defective bearings shall be replaced, and the fan shall be rechecked before further testing. The vibration shall be measured in two radial planes, 90 degrees apart, and in the axial direction. Measurements shall be made for each radial plane at the front and rear of the fan. Limiting value for vibration testing shall be as per ISO 14694/ISO10816..

V01.3.14.2. If measured vibration amplitude exceeds the specified maximum, or if the specified vibration measurements reveal unacceptable vibration at any frequency other than rated design operating speed, vibration amplitude shall be measured and recorded continuously as the fan is accelerated from a standstill to rated design operating speed, and as the unit coasts down from rated design operating speed to a standstill. The amplitude versus frequency chart shall be analysed by the Contractor (Fan Manufacturer) to determine the cause(s) of the unacceptable excessive vibration. Resonant frequencies shall be determined and shall be demonstrated as not to occur within fan operating ranges. The analysis shall be submitted to the Authority for approval and the cause(s) shall be corrected. The Authority shall be furnished final vibration amplitude readings on all fan bearings.

V01.3.15. Run-In Test

V01.3.15.1. At least one TEF and one TVF fan shall be operated continuously for a total of 8 hours, 4hours in the forward (exhaust) mode and 4 hours in the reverse (supply) mode of rotation. During reversal, fan shall be allowed to coast for a period of five minutes before being restarted in the reverse direction.

V01.3.16. Fan-Motor Unit Performance Test

V01.3.16.1. One TEF fan-motor and one TVF fan-motor unit that has satisfactorily passed the preceding test and inspections specified, shall be tested in accordance with the procedures specified in the AMCA 210/ISO 5801, latest edition, using a test set-up approved by the Authority.

V01.3.16.2. Fans shall be tested without flow cones or any other static regain devices. The fans shall be tested at the blade angle that shall produce the required volume of air at the required system pressure. This blade angle shall not be at its maximum setting. Test data shall be recorded on AMCA data submittal forms, or the equivalent thereof, as approved by the Authority. Certified test data, and certified performance curves for all of the co-ordinates specified shall be submitted to the Authority for approval.

V01.3.16.3. Performance tests shall cover the range of airflow rates from no flow to free air delivery. Performance tests of emergency fans shall cover this range of airflow rates in both directions of airflow. Actual fan performance shall not be less than contract values.

V01.3.16.4. Triaxial Strain gauges shall be applied to two blades per impeller and to the hub of the unloaded impeller of each type. To accurately measure strains and stresses developed in each rotor, one strain gauge at the midpoint and one strain gauge at the tip of blades on each side shall be applied on minimum of two blades. In addition, one strain gauge shall be applied on impeller hub for each strain gauged blade. The strains developed during performance testing shall be continuously measured and monitored. The measured strains produced under the performance test load shall be used to calculate the corresponding stresses. Stresses found shall not exceed sixty percent of the material yield strength at 250°C. The methods of strain measurement and stress calculation shall be submitted to the Authority for approval. The Contractor shall submit the manufacturer's notarised certification that the measured strains and the corresponding calculated stresses represent the strains and stresses developed in all other blades of the pre-production fan motor unit being tested. Calculated maximum expected stresses, and the design properties of the material used to fabricate the impeller blades and hub, shall also be submitted to the Authority for approval. Strain gauge testing shall be performed using the same testing set-up and operating conditions as the fan full scale performance test.

V01.3.16.5. Natural frequency readings of the fan blades shall be taken and included in the test report. Procedures used to determine natural frequency shall be submitted for approval. No blade's natural frequency shall occur within the fan rpm from 0 to 300% of the nominal fan operating speed.

V01.3.16.6. FOR TEF- In the event that the tests show that the fan-motor units do not comply with the requirements as to characteristics and performance, or that the brake kilowatt will exceed by five percent or more than the brake kilowatt shown in the theoretical data submitted by the Contractor, the fan-motor units will be rejected unless changes are made therein and tests repeated until the specific requirements are met. FOR TVF- Brake kilowattshould not exceed to the tolerance given in standard ISO 5801 (ISO 13348) or equivalent AMCA standard.

V01.3.16.7. Upon the completion of the fan-motor units' performance tests, submit two complete copies of all raw test data.

V01.3.16.8. After the completion of fan-motor units performance tests, submit for each fan-motor unit size, performance curves and tables of performance data calculated from shop test data, at each of the test points at each rotational direction.

V01.3.16.9. The tables shall consist of numerical values at each of the test points for the following:

Volume of air delivery in cubic meters per second

- Fan static pressure in Pascals
- Fan total pressure in Pascals
- Fan outlet velocity pressure in Pascals
- Fan total efficiency in percent
- Fan static efficiency in percent
- Kilowatt input to fan impeller
- Fan speed in revolutions per minute
- Current input in amperes
- Voltage in volts
- Motor power input in kilowatts and power factor
- Number of phases and frequency

V01.3.16.10. Submit fan-motor unit performance curves verifying the theoretical performance curves previously submitted. Test points shall be indicated on performance curves.

V01.3.17. Noise Test

V01.3.17.1. Preproduction unit which has satisfactorily passed all preceding tests and inspections specified shall be tested in accordance with the induct test procedure of ANSI 12.34/ BS EN 848/ ISO 13347/ ISO 3747/ DIN 45635 to obtain sound power level data at eight-octave band centre frequencies from 63 Hertz to 8,000 Hertz.

V01.3.17.2. Fan shall be tested with specified nominal airflow in both forward and reverse directions. Test data shall be submitted to the Authority for approval in tabular form.

V01.3.18. Reversal Test

V01.3.18.1. One fan motor unit which has satisfactorily passed all preceding tests and inspections specified shall be subject to reversal tests. These tests shall require operation at rated operating speed for approximately 3-1/2 hours with the unit oriented in the position that it will be installed, and shall require three cycles of rotation reversal. A cycle of rotation reversal is defined as reversal from one direction of motor impeller rotation to the other direction of rotation, and then back to the first direction of rotation.

V01.3.18.2. The reversal test shall begin with the fan unit operated in the forward direction of airflow for a period of 30 minutes.

V01.3.18.3. At the end of the first 30-minute period of operation in the forward direction of airflow, the motor shall be electrically reversed, with a 10-second time delay imposed between the interruption of power and re-energising of the motor for reversed rotation.

V01.3.18.4. After the motor has been re-energised, the fan shall be operated in the reverse direction of airflow for a period of 30 minutes.

V01.3.18.5. The test shall be continued, with alternating 30-minute periods of operation in the forward and reverse directions of airflow, until six rotation reversals have been performed. At the end of each 30-minute period of operation, the fan-unit motor shall be electrically reversed, with a 10-second time delay imposed between each change in direction until six rotation reversals have been performed.

V01.3.18.6. After three cycles of rotation reversal, i.e., six reversals of the direction of motor and impeller rotation have been performed, the fan-motor unit shall be operated for a period of 30 minutes.

V01.3.18.7. At the end of the last 30-minute period of operation, the fan shall be de-energised, and permitted to coast to a standstill.

V01.3.18.8. Resistance of the motor winding insulation shall be measured just prior to the start of the reversal test, and immediately after the end of the test. In addition, the temperature of the motor windings and of the motor frame shall be continuously recorded throughout the test. Certification of successful performance of the reversal test and certified test data shall be submitted to the Authority for approval.

V01.3.19. Installation methods

V01.3.19.1. All fans shall be furnished and installed as specified herein. The manufacturer's rigging instructions shall be carefully followed. The Contractor shall make certain that the installation of all supports, gaskets, hardware, etc., are accomplished with precision and the exercise of extreme care so as to assure safe, accurate and trouble-free fan installation.

V01.3.19.2. The fan installation shall be done in the presence of the Fan Manufacture's Field Service Representative.

V01.3.19.3. Prior to proceeding with the work described above, the Contractor shall submit for the Authority's approval eight copies of detailed drawings showing all fan installations including dimensions, supports, hardware, installation methods, and all other pertinent data.

V01.3.19.4. Fans shall be connected to transition companion flanges with 6 mm thick solid silicone gasket between.

V01.3.20. Field tests

V01.3.20.1. Upon completion of the installation of the ventilation equipment at the fan room and the installation and verification of the power and local control wiring, the Contractor shall notify the Authority in writing at least two weeks prior to the field testing to have the Authority present to witness the tests. The Contractor shall furnish written instructions for testing of the fan motor units in the field. This instruction shall be submitted as a part of the operating and maintenance instruction.

V01.3.20.2. Field tests shall be performed under the technical guidance and supervision of the Fan Manufacture's Field Service Representative. The Fan Manufacture's Field Service Representative shall provide the field test instrumentation and perform the tests. The Fan Manufacture's Field Service Representative shall measure and record the vibration amplitude; power consumption; no-load, starting and full load voltages; starting and full load currents; and acceleration time.

V01.3.20.3. Time of operational testing shall be two hours per fan; one hour in each flow direction. All fans in a station shall be operating simultaneously when determining and recording the electrical measurement. Prior to the operational tests the vibration and electrical measurements shall be recorded for each fan motor unit at design speeds in each direction.

V01.3.20.4. Testing for the ventilation equipment shall not be undertaken until electric service and local controls can be provided for testing.

V01.3.20.5. Each fan motor unit shall be checked for obviously rough operation after the fans are installed. Defective bearings shall be replaced with new bearings and the fan(s) shall be rechecked. Amplitude and frequency of radial and axial vibrations at the bearings shall be measured, recorded, and checked for conformity to the Specifications.

V01.3.20.6. Each fan motor unit on which the specified vibration field tests have been successfully performed shall be tested to confirm that such fans are operational. Each emergency fan motor unit shall be proven operational in both directions of airflow, including one reversing of direction of rotation.

V01.3.20.7. When two fans are to start, starting sequence shall be provided with 20 seconds interval. Both fans shall achieve full speed in 35 seconds. When both fans are to be reversed, fans shall be de-energized for 30 second. After 30 seconds, the selected fan shall be energised for reverse rotation with successive fan energised at 20 seconds.

V01.3.20.8. Electricians to energise the ventilation equipment where required and assist the Contractor during testing shall be provided by the Contractor.

V01.3.20.9. Any defect that develops within the ventilation equipment during the test shall be corrected by the Contractor at no additional cost to the Authority.

V01.3.20.10. Any defect that develops with the installation work during the test shall be corrected by the Contractor at no additional cost to the Authority.

V01.3.21. After completion of all field tests and after the final visit by the Fan Manufacture's Field Service Representative, Contractor shall submit a field test and inspection report. Field test report shall include copies of raw data, measured results, calculations, and all data derived from tests to confirm compliance with specified performance, noise, vibration and equipment efficiencies.

TUNNEL VENTILATION FANS		
Type		Tubular Reversible Axial Flow
Noise Criteria		Refer to Notes
Reversibility		100% of nominal capacity in each direction
High Temperature Operation		2 Hour @ 250 °C
Capacity		as per BOQ
Fan	Blade	Aerofoil Construction, Dynamically Balanced
	Material	Alloy Aluminum
	Bearings	Spherical roller (single row)
	Hub	Cast Aluminum
	Casing	Rolled Steel Sheet, Heavy Gauge
	Shaft	Solid Carbon Steel
	Mounting	Shaft Key And Positive Locking Device
Drive Arrangement		Direct Drive (mounted on motor shaft)
Motor	Type	TEFC Induction Motor,EFF-1, Continuous Duty
	Design	As Per Relevant IEC
	Connection	Three Phase, 415 V, 50 Hz, AC Power Supply
Mounting Arrangement		Base frame for floor mounting
Lifting Arrangement		Lifting Eye At Suitable Location and number.
Paint		Fan structure Hot dip galvanized.
Fire Rated Enclosure		Fire rated demountable enclosure is required only on fan and not on attenuator and transition piece.
NoiseAttenuator	Type	Square, Rectangular Flange Type
	High Temperature Operation	2Hour @ 250 °C
	Construction	To Comply with DW 142 Class B Code
	Casing	1.6 mm thick Hot Dipped Galvanized Sheet Steel
	Casing Material	Galvanized steel sheet
	Acoustic Fill	Mineral wool or Fiber Glass With Class 'O' Flame Spread/ As per class ASTM E 84
	Internal	0.8 mm thick perforated SS-316.
	Splitters	0.8 mm thick perforated SS-316.
	Mounting Arrangement	Suitable Bracket For Floor/Wall Mounting

	Lifting Arrangement	Lifting Eye At Suitable Location And Number
	Casings To Be Formed With Either stand Up Or Lock Formed Seams With Mastic Sealant	

Notes

1) Pressure drops to be verified by Contractor based on final equipment offered.

2) Length of noise attenuator to be determined by the Contractor based on the equipment offered and the following:

Tunnel noise criteria is 80 dB(A) during operation of tunnel ventilation equipment.

Platform noise criteria is 75 dB(A) during operation of tunnel ventilation equipment.

Tunnel Ventilation Fan Room Noise criteria is 85 dB(A) during operation of tunnel ventilation equipment.

External noise criteria is 55 dB(A)at nearest property line during operation of tunnel ventilation equipment

3) The fans shall be as per DMRC specifications enclosed. All accessories mentioned in specifications shall be included in the tender.

4) Vender shall furnish following data with his offer

i) Fan performance curve for each direction of rotation

ii) Dimensional Sheets

iii) Fan Data Sheets

iv) Fan sound power levels for complete octave band for forward & reverse direction.

TRACKWAY EXHAUST FANS		
Type-		Tubular Tube Axial Flow with short casing
Reference Code / Standard		BS EN ISO 9001
Capacity		As specifiedin BOQ
Flow Direction		Unidirectional (Extract)
Total Pressure		As specified
Noise Criteria		Refer to Notes
High Temperature Operation		2 Hour @ 250 °C
FAN	Blade	Aerofoil Construction, Dynamically Balanced , Adjustable
	Material	Cast Aluminum / Steel
	Bearings	Fan mounted on motor Shaft
	Hub	Cast Aluminum
	Casing	Rolled Steel Sheet, Heavy Gauge

	Shaft	Impellor mounted on motor shaft
	Mounting	Shaft Key And Positive Locking Device
Drive Arrangement		Direct Drive
Motor	Type	TEFC Induction Motor, IE2 efficiency, Continuous Duty
Motor	Design	Relevant IEC standard
Motor	Connection	Three Phase, 415 V, 50 Hz, AC Power Supply
Paint		Epoxy Paint after Surface Treatment For Corrosion/ Hot Dipped galvanized surface
Fire Rated Enclosure		Fire rated demountable enclosure is required only on fan and not on attenuator and transition piece.
NoiseAttenuator	Type	Square, Rectangular Flange Type
NoiseAttenuator	High Temperature Operation	Two Hour @ 250 °C
NoiseAttenuator	Construction	To Comply with DW 144 Class B Code
NoiseAttenuator	Casing	1.6 mm thick Pre GSS
NoiseAttenuator	Casing Material	GSS Grade Z 2 G 275
NoiseAttenuator	Acoustic Fill	Fiber Glass With DETR Class ‘O’ Flame Spread or class A of ASTM E 84
NoiseAttenuator	Internal	0.8 mm thick perforated SS-316
NoiseAttenuator	Splitters	0.8 mm thick perforated SS-316
NoiseAttenuator	Mounting Arrangement	Suitable Bracket For Ceiling Suspension
NoiseAttenuator	Lifting Arrangement	Lifting Eye At Suitable Location And Number
NoiseAttenuator	Casings To Be Formed With Either stand Up Or Lock Formed Seams With Mastic Sealant	

Notes

1) Pressure drops to be verified by Contractor based on final equipment offered.

2) Length of noise attenuator to be determined by the Contractor based on the equipment offered and the following:

Tunnel noise criteria is 80 dB(A) during operation of tunnel ventilation equipment.

Platform noise criteria is 75 dB(A) during operation of tunnel ventilation equipment.

Tunnel Ventilation Fan Room Noise criteria is 85 dB(A) during operation of tunnel ventilation equipment.

External noise criteria is 55 dB(A)at nearest property line during operation of tunnel ventilation equipment.

3) The fans shall be as per DMRC specifications enclosed. All accessories mentioned in specifications shall be included in the tender.

4) Vender shall furnish following data with his offer

i) Fan performance curve for each direction of rotation

ii) Dimensional Sheets

iii) Fan Data Sheets

iv) Fan sound power levels for complete octave band for forward & reverse direction

Section V02: Tunnel Ventilation System Dampers

TABLE OF CONTENT

V02.1. General

V02.1.1. This Section specifies the requirements for furnishing pneumatically operated dampers, nozzles and appurtenances as specified herein. Dampers shall be the product of a single manufacturer whose name shall appear on the performance curves and other data submitted and who shall have previously furnished bypass dampers to rail transit agencies for a period of at least five years..

V02.2. Quality control

V02.2.1. Materials and workmanship shall be in accordance with the latest edition of the following standards and codes to the extent specified herein. The publications listed below form a part of these specifications to the extent referenced. The publications are referred to in the text by basic designation only.

V02.2.1.1. Air Moving and Control Association (AMCA):

500, Test Method for Louvers, Dampers and Shutters.

V02.2.1.2. American National Standards Institute (ANSI):

C1, Specifications of General Requirements of a Quality Program

V02.2.1.3. American Society for Testing and Materials (ASTM):

A36, Structural Steel.

A123, Zinc (Hot Galvanised) Coatings on Products Fabricated from Rolled, Pressed and Forged Steel Shapes, Plates, Bars, and Strip.

A193, Alloy Steel and Stainless Steel Bolting Materials for High Temperature Service.

A239, Locating the Thinnest Spot in Zinc (Galvanised) Coating on Iron or Steel Articles by the Preece Test (Copper Sulfate Dip).

A525, Steel Sheet, Zinc Coated (Hot Galvanised) by the Hot-Dip Process.

V02.2.1.4. American Welding Society (AWS):

D1.1, Structural Welding Code - Steel.

V02.2.1.5. National Electrical Manufacturer's Association (NEMA):

ICS, Industrial Controls and Systems.

IS1.1, Enclosures for Controls and Systems.

MG-1, Motors and Generators.

V02.2.1.6. National Fire Protection Association (NFPA):

130, Fixed Guideway Transit Systems.

V02.2.1.7. Underwriter's Laboratories, Inc. (UL):

508, Industrial Control Equipment.

V02.2.2. Submittals

V02.2.2.1. Before giving the manufacturer Notice to Proceed, the Contractor shall submit to the Authority for review and approval, the names and qualifications of the manufacturer of tunnel ventilation system damper units. Qualification statement shall include but need not be limited to the following data:

1. Theoretical performance curves for dampers proposed to be furnished under this Contract.
2. Actual performance curves verifying the theoretical performance curves previously submitted shall also be furnished as part of the damper unit test results. Performance curves shall be plotted to such scales as will make it possible to read the data accurately.
   - ❖ The damper performance curves shall be damper characteristic curves as follows:
     - – Curve plotted with ordinate as pressure drop in Pascals versus face velocity in meters per second.
     - – Curve plotted with ordinate as duct pressure in Pascals versus leakage in percentage of maximum flow.
   - ❖ The following information shall be printed in each performance curve:
     - – Project title.
     - – Name and address of damper manufacturer.
     - – Name and address of damper operator manufacturer.
     - – Contractor's name and address.
     - – Damper designation number.
     - – Air density.
     - – Damper face area.
     - – Damper assembly net free area.
     - – Damper operator model number.
     - – Electrical/Pneumatic characteristics of damper operator.
     - – Electrical characteristics of damper operator space heater, including voltage and kilowatt input.
   - ❖ Manufacturer's quality assurance program.
   - ❖ A complete list of projects on which similar tunnel ventilation dampers for rail transit projects have been installed or furnished. List shall include:
     - – Name of authority or user.
     - – Contract number(s)
     - – Original installation date(s)
     - – Current condition of equipment, including estimate of remaining useful life
     - – A list of all known failures including, their apparent causes, corrective work affected, and a description of equipment service and operating conditions.
   - ❖ List of components proposed to be purchased from other manufacturers, giving name of manufacturer, type and characteristic of each item and applicable data requested under paragraph 1 through 3 above.

V02.2.2.2. The Contractor shall submit to the Authority a Certificate of Compliance signifying that equipment to be furnished under this Contract meets the requirements specified herein.

V02.2.2.3. Within 14 days after successful completion of all factory tests specified herein and of any additional tests conducted at the Contractor's own option, the Contractor shall submit the following:

- Certified results for all tests conducted. All test data shall be bound in one report. The test report shall be indexed and cross-referenced in an easily understood manner.
- All records and results of non-destructive examinations made at completion of each examination.
- Field test procedures.

V02.2.2.4. Supply the Authority with spare damper operators, identical to the operators installed to operate the dampers. The damper operator motors shall be complete and labelled with the pneumatic operator characteristics.

V02.3. Technical and installation requirements

V02.3.1. Description

V02.3.1.1. Dampers shall be furnished complete with damper mounting frames / joining angles for each damper module and all components and incidentals as specified herein; with all structural support elements and hardware required for installation of the damper modules into composite damper units, and with any additional accessories which may be needed in order to meet the performance requirements as provided in these Specifications.

V02.3.1.2. All like components shall be furnished by a single supplier.

V02.3.1.3. Each damper module shall have integral channel frames with interconnecting linkage between modules and operators which shall permit all blades in damper assembly to operate in unison. Modules shall be individually removable from composite assembly. All damper modules shall be surface mounted against the face of structural steel members, (columns, mullions, lintels, beams and embedded framing members) which shall be furnished by the damper manufacturer, and installed by the installing Contractor. Structural steel members shall have pre-drilled companion flanges matching the size and spacing of mounting holes in each damper module frame.

V02.3.1.4. Dampers and damper companion flanges may be fabricated in multiple sections where required. The sections shall be interconnected with bolted splice plates. The sections shall be of such size, which can be brought into the fan rooms and vent shafts through the access provided and to facilitate handling, erection and disassembly. Prior to fabrication, the existing concrete openings for dampers and the equipment access shall be field verified.

V02.3.1.5. Linkages and bearings of all damper modules shall be arranged in such a manner, that they are easily accessible upon removal of gasketted cover plates, without removal of entire damper module.

V02.3.1.6. All dampers furnished shall be suitable for installation in either a vertical plane or a horizontal plane, as required.

V02.3.1.7. The dampers shall be designed to be readily assembled in the field from modular panels. Each damper panel shall be of the multiple parallel / opposed blade type, with an independent channel frame; and shall be factory assembled complete with frames, blades, shafts, bearings, seals, linkage, and all accessories required to erect the modular panels into composite damper units which are functional as specified herein. Dampers shall be furnished complete with all structural support members and hardware required to complete the installation.

V02.3.1.8. Multiple modular panel dampers may be operated by use of suitable operating mechanisum.

V02.3.1.9. Dampers shall be arranged for pneumatic operation to two blade positions: fully-open and fully-closed. Each damper shall be furnished complete with pneumatic operators sufficient in number and capacity to actuate all modular panels in a damper unit in unison under the operating conditions specified herein. Dampers shall be suitable for continuous operation in either open or closed position.

V02.3.1.10. Dampers shall have a net free face area of not less than 80 percent measured to the inside of the damper frame clear opening when blades are fully open.

V02.3.1.11. Upon loss of compressed air, dampers shall move to the power-off position (open or closed) as indicated by the Contractors design.

V02.3.1.12. Dampers shall be so designed that the dampers will be fully operational in accordance with the performance requirements specified herein after exposure to an airstream temperature of 250 degrees C for two hour. Dampers and components shall be capable of withstanding the stresses caused by pressure transient pressures from train piston action, and by reversal of airflow and thermal shock caused by temperature changes of from 0 to plus 250 degrees C. Submit manufacturer's certificate of compliance and the results of previous test if conducted for certification of such requirements.

V02.3.1.13. Each damper module shall be provided with limit switches for remote indication of the fully open fully closed position of the damper. Switches shall be provided with independent contacts mounted to positively detect full-open and full-closed positions. Limit switches for dampers required to operate in high temperature shall be suitable for operating at 250 degrees C for two hour.

V02.3.1.14. For multiple module dampers, and dampers that operate in a group, limit switches shall be wired in series to provide a common open or closed indication for each damper unit, or damper group.

V02.3.1.15. .

V02.3.1.16. Damper and Actuators assembly shall be capable of being fully cycled (open to close to open, or vice versa) for a minimum of 100,000 cycles before failure occurs. Damper manufacturer shall submit a certificate along with test data guaranteeing this performance.

V02.3.2. Damper fabrication and components

V02.3.2.1. Damper blades shall have an airfoil cross-section and shall be fabricated of Type 304 stainless steel each skin should be a minimum thickness of 1.2 mm. The width of the blades measured in the direction of airflow shall not be less than 150 mm and shall not be greater than 300 mm. Damper blades in the open position shall not extend beyond the damper frame. Damper blades shall have metal to metal overlap in the closed position. Blade edge sealing strips, regardless of their composition, will not be permitted as a substitute for a true blade to blade overlap.

V02.3.2.2. Damper blade shafts shall be fabricated of stainless steel Type 304. Blade shafts shall be full-length construction and shall be not less than 20 mm in diameter or square. . The design of the damper blade shafts shall incorporate the devices required for locking the blades onto the shafts. Damper blade shaft axis shall always be horizontal.

V02.3.2.3. Damper blade deflection, with blade supported by shaft, shall not exceed 1/360 of the span length between centres of shaft bearings with damper in closed position while withstanding the maximum combined differential pressure of 2500 Pa and maximum temperature of 250 degrees C.

V02.3.2.4. The damper blade and shaft assemblies shall be supported at each end by means of self-lubricating sleeve type bearings, suitable for operating at 250 degrees C for two hour. Bearing mounting shall be external to frame.

V02.3.2.5. Damper linkage shall be external heavy duty industrial type, fabricated of stainless steel Type 304 not less than 6 mm by 20 mm flat bars. Linkage shall interconnect damper blade shaft crank arms which shall be fabricated of stainless steel not less than 5 mm thick. The linkage bearings shall be fabricated of brass or other material suitable for the specified operating conditions or as per best international manufacturing standard/ practices.. .

V02.3.2.6. Damper frames shall be a channel cross-section with not less than an 200 mm or greater than 300 mm web and not less than 50 mm flanges on the both sides and shall be fabricated of stainless steel Type 304 with a minimum thickness of 3 mm. The contactor may recommend alternative international practices/method for mounting arrangement. The corners of the frames shall be welded and reinforced by means of riveted gusset plates. Linkage elements shall be sized so that the maximum deflection of any element shall not exceed L/360, where "L" is the length.

V02.3.2.7. Pneumatic operated dampers shall be furnished complete with all structural support elements necessary for the installation of the dampers, including the following: all intermediate supports, both horizontal and vertical; all clip angles and other framing members as required at the head, sill, mullion and jambs of each damper assembly; and all screws, bolts, nuts, washers and other hardware required to complete the installation. All intermediate supports, framing members, and hardware required for assembly and installation of the damper modules shall be fabricated of stainless or cadmium plated steel.

V02.3.2.8. Lifting lugs/ holes/eves shall of suitable strength shall be provided in sufficient number to facilitate future on-site installation and removal. .

V02.3.2.9. Damper companion flange grid assemblies shall match the damper frame.

V02.3.2.10. Mullion supports shall be designed by the Contractor. The mullions shall be the full length and width of the dampers. Mullion supports shall be of galvanised steel and shall have punched or drilled holes, equally spaced for damper module attachments. Number of holes and space between the holes shall be selected by the Contractor. Mullion supports shall be installed by the Contractor. The Contractor may recommend alternative method for mullion attachment to damper companion flanges and align the equipment with the flange.

- ❖ Flanges shall have punched or drilled holes equally spaced not more than 150 mm on centres.

- In accessible areas, fasteners shall be hexagonal head bolts with hexagonal nuts, provided with heavy-duty lock washers.
- In inaccessible areas, fasteners shall be hexagonal head tap bolts, provided with heavy-duty lock washers.
- Bolts shall be not less than 12 mm in diameter. Nuts and bolts shall conform to the requirements of ASTM A 193, Grade B8M or Grade B8MA, equivalent to AISI Type 316, with suitable lock washers.

V02.3.2.11. Damper operator mounting brackets shall be fabricated of not less than 3mm~~9 mm~~ thick stainless steel Type 304 and shall be bolted to the mounting surface. Mounting bracket shall be constructed in such a manner that bracket cannot be moved by hand to cause binding or misalignment of bearing(s) and damper shaft(s).

V02.3.2.12. Contractor shall provide a 6 mm thick fire rated gasket covering the full width of each flange between damper frames and damper companion frames and between damper frames and other associated companion flanges. Gasket material shall be suitable for 250 degree C for two hour without emitting toxic or noxious fumes.

V02.3.2.13. Mounting members for Wall Mounted Dampers. All mounting members needed to install each wall mounted damper in its respective opening shall be furnished and installed by the Contractor. All mounting members shall be galvanised steel angles all sides, size 80 mm by 80 mm by 8 mm. The mounting members shall be fastened to the damper by means of stainless steel fasteners. Each damper shall be brought to the site as an integral unit, except that mounting members shall be fastened and installed in the field. The mounting members specified in this paragraph are in addition to the module and damper frames specified herein.

V02.3.2.14. Provide the Authority with technical support bearings. Quantity of technical support bearings shall be one percent of each type used on dampers. Store bearings in secure storage containers with permanent labels identifying number, type, manufacturer, bearing location on dampers, and the Authority Construction Contract Number.

V02.3.3. Damper operator requirements

V02.3.3.1. The damper operators shall be pneumatic type. Electro-Hydraulic operators shall not be used. The actuators shall be capable of actuating the dampers as specified herein against differential pressure of 2500 Pa across the dampers. The operators shall be capable of changing the position of the dampers from fully closed to fully open, or from fully open to fully closed within a period of not more than 30 seconds. Time duration to close or to open the damper shall be adjustable in the field. The actuators shall be selected and their required quantity shall be determined, such that the normal torque output required for each damper or damper section does not exceed two-thirds of the rated actuator capacity. This selection criterion provides that each actuator has at least 50 percent excess capacity. However, in no case shall there be less than two pneumatic actuators provided per damper installation, and each actuator shall be linked independently to damper sections of equal size. Pneumatic actuators shall be able to operate continuously under the specified ambient temperature conditions.

V02.3.3.2. Linkage from the damper actuator shall be fabricated of stainless steel Type 304 and shall be connected to the interconnecting blade linkage with a stainless steel pin, such that full force of operator is applied to the blade connecting linkage.

V02.3.3.3. NOT USED

V02.3.3.4. NOT USED

V02.3.3.5. The actuators shall be furnished with spring actuated devices capable of driving the dampers to their "POWER OFF" positions within a period of 15 seconds after the operators are de-energised. The "POWER OFF" position of a damper (normally open or normally closed) is defined as the position which the damper assumes when its operators are de-energised. The spring return devices shall be fully operational as specified throughoutand following exposure to ambient and air stream temperatures of 250 degree C for two hour.

V02.3.3.6. Conduit boxes shall have tightly fitting, gasketted covers designed to resist the entrance of dust and fluids; and shall have threaded conduit openings. All electrical components, conduit and boxes shall be weatherproof. Conduit boxes shall be mounted to the motor mounting plates.

V02.3.3.7. The initial charge of lubricants for damper components shall be supplied by the manufacturer.

V02.3.3.8. Co-ordinate with damper manufacturer the installation of damper pneumatic operators from operational and service standpoint.

V02.3.4. Damper finishing

V02.3.4.1. All galvanised parts shall have either a hot-dipped or an electro-deposited zinc coating. The weight of the coating shall be not less than 750 grams per square meter of surface. The zinc coating shall be performed after the material is fabricated. The use of zinc pigmented paint in lieu of galvanising will not be allowed. The galvanising shall conform to ASTM A 123; and withstand an eight dip Preece Test in accordance with ASTM A 239.

V02.3.5. Nameplates

V02.3.5.1. Each damper shall be provided with a stainless steel nameplate permanently stamped with the name and address of the manufacturer, Contractor's model type, serial number and the Authority's designated damper number.

V02.3.5.2. Each damper pneumatic actuator shall be provided with stainless steel nameplate.

V02.3.5.3. Nameplates shall be attached to respective component in a location conspicuous after installation.

V02.3.6. Screens

V02.3.6.1. Screens mounted on damper module frame shall be one-inch mesh No. 10 U.S.S. gauge galvanised steel wire. Each screen shall be complete with a frame for rigidity. The screen shall be reinforced across the shorter dimension with 30 mm by 30mm by 3mm galvanised steel angles on 600 mm maximum centres.

V02.3.6.2. Screen companion flanges shall be bolted to damper companion flanges with bolts spaced not more than 300 mm on centre.

V02.3.7. Factory damper tests

V02.3.7.1. The Authority may, at his option, witness any or all of the tests specified herein. The Contractor shall notify the Authority, in writing, in not less than three weeks in advance as to the location and dates of the factory tests.

V02.3.7.2. One damper unit shall be subjected to tests. The test shall be conducted in a test facility located either at the manufacturer's plant, or at a suitably equipped testing laboratory. The test facility shall be approved by the Authority.

V02.3.7.3. The damper shall be tested in accordance with AMCA 500-D-58 and AMCA 510-04, the latest edition using a test set-up approved by the Authority as appropriate for the intended installation of the dampers. Test data shall be recorded on AMCA data submittal forms, or the equivalent thereof as approved by the Authority. Certified test data, and certified performance curves for all of the co-ordinates specified in these Specifications shall be submitted to the Authority for approval. Minimum test section shall be 1200 mm by 1200 mm.

V02.3.7.4. Conduct the following performance tests:

- ❖ Maximum leakage in percentage of flow with 2500 Pa pressure differential across the closed damper.
- ❖ Maximum pressure drop across damper in fully open position with a uniform face velocity of 10 m/s.
- ❖ A detailed analysis for submission by the manufacturer to demonstrate that the various damper components at their point of critical stress do not exceed the endurance limit stress of the material. Calculated maximum expected stresses for both the normal design pressure condition and the test condition, together with design properties of the material used to fabricate the damper blades and shafts, shall be submitted to the Authority for approval.

V02.3.7.5. Operational Test: The damper, while remaining in the fully closed position, shall be capable of operating & closing and withstanding a differential pressure of not less than 2500 Pa.

V02.3.8. Installation method

V02.3.8.1. All dampers, connecting bars, linkages and operators shall be installed and adjusted so that: when a damper is fully open, the damper blades shall be parallel to air flow to provide minimum friction loss and obstruction to airflow, when a damper is fully closed, the damper blades shall be perpendicular to the airflow with seals pressing against mating surfaces along their entire length to provide tight closure and minimum air leakage.

V02.3.8.2. There shall be no flutter, rattling or vibration of damper, connecting bar and linkage either when the damper is operating or when the damper is in the fully open or fully closed positions. Each damper shall be installed so as to provide smooth operation, opening and closing without shock or slamming.

V02.3.8.3. All damper linkage shall be properly installed and connected to its perspective operator to prevent blade flutter and to insure against connecting bar and linkage distortion or binding during operation. Undue flexure or bending of connecting bars and linkage shall be cause for rejection. Such connecting bar and/or linkage shall be replaced with either a corrected design, higher strength materials, proper size of components or a combination of the aforesaid, as required.

V02.3.8.4. Damper and Damper Openings. Particular attention is called to the fact that nominal dimensions are often indicated on the drawings for construction of the dampers. However, the actual openings where dampers are to be installed may vary from the indicated dimensions. In providing dampers to close these openings, the Contractor shall verify all dimensions in the field and shall design and build each frame to fit the respective opening, without leaving spaces between the frame and structure. All slight unavoidable spaces between the frame and the structure shall be filled to the satisfaction of the Authority, so that the damper openings shall be completely airtight. The aforesaid spaces shall be filled with grout or neat Portland cement or other approved sealing materials, all properly bonded to the existing surface.

V02.3.9. Field service

V02.3.9.1 The Contractor shall provide a field service Representative and inspection to the Authority to ensure that the dampers and damper operators supplied therein are properly installed and tested.

V02.3.9.2 Field service shall be performed periodically as required during the period of performance of this contract.

V02.3.9.3 The Authority shall be advised in writing of the name and title of the proposed Damper Manufacture's Field Service Representative, who upon the Authority's approval shall have complete authority to represent and to act for the Contractor.

V02.3.9.4 The duties, responsibilities, and qualifications of the Damper Manufacture's Field Service Employer's Representative shall be:

- ❖ Advise installation Contractors on the proper procedures for the installation of the damper equipment.
- ❖ To have a thorough knowledge of the damper systems.
- ❖ To have a thorough knowledge of the testing of all material and equipment supplied.
- ❖ To prepare and submit to the Authority a typewritten report on all activities and findings for each visit within 15 working days of each visit. The final report shall give results and findings of field tests below. Payment for each visit will not be authorised until written service reports have been received and accepted by the Authority.

V02.3.9.5 Field Test:

- ❖ The Contractor shall furnish written instructions for testing the dampers in the field as part of the operating and maintenance instructions.
- ❖ Each damper shall be subject to rotation reversal tests. A cycle of rotation reversal is defined as reversal from fully open to fully closed position, and then back to fully open position. Each damper shall require five cycles of rotation reversal.
- ❖ After completion of reversal tests each damper operator shall be de-energised and checked to confirm that it is driven to its "power off" position within 15 seconds after being de-energised.
- ❖ Damper equipment shall be energised and temporary connections shall be made where required.

- ❖ Any defect that develops within the equipment during the test shall be corrected by the Contractor at no additional cost to The Authority.
- ❖ Any defect that develops with the installation work during the test shall be corrected by the Contractor at no additional cost to the Authority.

V02.3.10 Air Nozzle

V02.3.10.1 Access:

No claim shall be entertained for difficulties in access to the site of works, crossing of drawings ponds, railway tracks, culverts, telephone duct, electric culverts, rocky area, seepage of water from any source etc.

The contractor shall have to start the work at the available reach. The contractor shall not be eligible for any compensation on account of the delay caused due to non-availability of the site to be arranged by the employer except extension to date of completion.

V02.3.10.2 Scope:

- ❖ Detail engineering preparation of execution drawings, Manufacturing, Supply, Installation, Testing and commissioning of Nozzle for Tunnel Ventilation system including necessary civil works including provision of hooks in the roof to facilitate lifting of Nozzles for installation. These hooks are to be left for future use by the maintenance branch. Closing of access cutouts around the Top Discharge Nozzle by M.S Steel Work as approved by Employer is included in the scope of this contract.
- ❖ Contractor is required to verify the Nozzle Size and design as per the site requirement. Final Nozzle analysis is in the scope of this contract. Any Modification required to achieve the desired performance is under the scope of this contract.

V02.3.10.3 Nozzle Detail:

- ❖ Nozzles shall be fabricated as per approved Drawings. All supports shall be of hot dip galvanised steel. All bolts and nuts with nozzle shall be provided with lock nuts and of SS-316 / SS-304 the nozzle installation details shall be as per drawing.
- ❖ If pressure plate (of GI material) is used in the construction, then nut and bolt of GI material on pressure plate only will be acceptable.
- ❖ Lifting lug, Parting flange, flow straightener, Top/bottom sheet, side sheet, jointing sheet, End flange shall be made up of SS-304 conforming to latest standards with latest amendment (if any). The body sheet shall be 2.5mm thick stainless steel (SS304) including all supporting angles.

V02.3.10.4 Welding:

- ❖ All welding processed by manufacturer shall be as per manufacturer recommendation. . Contractors shall provided copies of relevant standards for the process used.

V02.3.10.5 Design Consideration:

- ❖ The equipment designed, manufactured and installed so as to achieve a service life of 40 years.

V02.3.10.6 Quality Assurance:

The detailed quality assurance plan shall be submitted by the contractor to the employer for approval and implementation during the execution of the work.

TUNNEL VENTILATION DAMPERS		
Type		Tunnel Ventilation Damper with Pneumatic Actuators with pneumatic actuators
Reference Code / Standard		UL 555, BS 476 Part 20.
Tag No		Tag No To Be Marked On Damper With Black Letter. SS Tag To Be Firmly Attached
High Temperature Operation		TwoHour @ 250 °C
Fire Rating		The Fire Rating Of Damper Shall Have The Same Fire Rating As The Ductwork Or Wall In Which It Is Installed
Service		Continuous Duty
Performance		Based on Air Density Of 1.2 kg/m^3
Mounting		Horizontal Or Vertical
Construction		In Two Module – Minimum, Each With Separate Pneumatic Actuator
Differential Pressure		2500 Pascal
Damper Free Area		Not Less Than 80 % Measured To Specified Damper Size
Damper Operating Mounting Bracket		Stainless Steel – 304, 3 mm Dia
Time To Change Position		30 sec Maximum From Fully Open To Close Position
		15 sec Maximum To The Power Off Position
Leakage		As Per UL 555 S Class I Requirement
Frame Construction		Stainless Steel -304 (50 mm flanges on both side, 3 mm thick)
Blade	Pressure Drop	40 Pascal @ 10 Mtr. / sec. Air Velocity
	Construction	Stainless Steel – 304 / Aluminum Alloy, Aerofoil Design
	Type	Parallel Blades / Opposed Blade
	Blade Thickness	Extruded Section Of 1.2 mm Thick
	Linkages	Stainless Steel – 304, 6 mm x 20 mm Flat Bar
	Shaft	Stainless Steel – 304, 20 mm Dia
	Bearing	Self Lubricated Sleeve Bearing
	Bearing Rating	TwoHour @ 250 °C0
Crank Arms		Stainless Steel – 304, 5 mm Dia
Actua	Should Be Simple In Design With Minimum Moving Parts	

	Torque Capacity	50% Excess Torque
	Differential Pressure	2500 Pascal (Max)
	Temperature Rating	Two Hour @ 250^{0} C
	Return To Fail Safe Position	Spring SS 304
	Actuator Type	All Pneumatic

Notes

1) Dampers shall be as per specifications enclosed.

2) Dampers shall be designed for operation up to air temperature of 250 deg. C. for two hour Dampers and its components shall be capable of withstanding stresses caused by Temperature changes up to 250 deg. C. Limit switches shall also be suitable for temperature up to 250 deg.

Section V03: Noise and Vibration Control

TABLE OF CONTENT

General

V03.1.1. This Section specifies the requirements for furnishing sufficient noise and vibration measures on his plant/equipment. Sound attenuators shall be the product of a single manufacturer who shall have previously furnished such acoustic equipment for a period of at least five years.

V03.2. Quality control

V03.2.1. The Contractor shall submit to the Authority a Certificate of Compliance signifying that equipment to be furnished under this Contract meets the requirements specified herein.

V03.2.2. Within 14 days after successful completion of all factory tests specified herein and of any additional tests conducted at the Contractor's own option, the Contractor shall submit the following:

- ❖ Certified results for all tests conducted. All test data shall be bound in one report. The test report shall be indexed and cross-referenced in an easily understood manner.
- ❖ All records and results of non-destructive examinations made at completion of each examination.

Field test procedures

V03.2.3. Nameplate shall be attached to each item of acoustic equipment showing Manufacturer's name and address, serial and model numbers and the normal direction flow.

V03.2.4. The sound attenuators shall be tested on dynamic insertion loss performance in accordance with BS4718 or ASTM-E477 'Duct to reverberation room" method with air flowing through the sound attenuator at rated capacity, in both forward and reverse flow direction. The test section shall be at the middle of a long straight duct run to reduce the effect on random incidence of the sound wave and to obtain a more reliable pressure loss rating of the air downstream of the sound attenuator.

V03.2.5. Acoustic material for the sound attenuator shall be tested on sound transmission loss performance and sound absorption coefficients in accordance with ASTM E90-61-66 G70, E413-73 and ASTM C423-66 whichever is appropriate.

V03.2.6. The sound attenuators shall be classified as non-combustible in accordance with BS476 Class O or class A OF ASTM E 84

V03.3. Technical and installation requirements

V03.3.1. Sound attenuators

V03.3.1.1. The sound attenuators shall be selected to enable noise limits inside and outside to be achieved.

V03.3.1.2. The sound attenuators selected shall be suitably matched to the system and shall add as little as possible to system resistance. The geometry of selected attenuators shall not result in requirements for sharp transformation in adjacent ductwork, shall not interfere with adjacent services or with reasonable access to services and shall not adversely affect the aerodynamic performance of the system or encourage regeneration of noise local to the attenuator.

V03.3.1.3. The sound attenuator shall be rectangular in section with flanges on both ends. Outer casing shall be made of a minimum 1.6mm thick galvanised steel while the internal partition shall be made of not less than 0.8mm thick perforated stainless steel (SS-316). Casing shall be properly considered as a part of the attenuation system and the casing thickness shall be chosen to include consideration of the acoustic properties required.

V03.3.1.4. The steel sheets for the outer casing and the perforated sheets of the splitters shall be made from continuous sheets.

V03.3.1.5. The inlets and discharge ends shall be bell mouth shape with the intake bell mouth made from a minimum of 0.8mm stainless steel (SS-316), properly jointed to the perforated sheets.

V03.3.1.6. The splitters shall be attached to the casing with reinforcement such that no part of the splitters shall vibrate or detach from the casing during operation. The perforated sheets shall be properly stiffened to avoid deformation due to the weight of other splitter modules.

V03.3.1.7. The infill shall be of inorganic mineral of glass fibre of at least 48kg/m^3 and be packed under at least 10% compression to eliminate voids due to vibration and settling. Material shall be inert and vermin and moisture proof.

V03.3.1.8. All cut surfaces of the sheet metal and welded spots shall be coated with zinc rich paint.

V03.3.1.9. All seams of the sound attenuators shall be sealed with a duct sealing compound and shall be air tight when operating at 1.5kPa static pressure and rated capacity.

V03.3.1.10. Sound attenuators shall not fail structurally when subjected pressure fluctuations of 2 kPa.

V03.3.1.11. The design pressure drop shall not exceed the specified nominal pressure drop and the insertion loss shall be equal to or greater than specified.

V03.3.1.12. Duct sound attenuators shall be located such that noise break-in ductwork on the quiet side of the attenuator or duct breakout between the noise source and the attenuator is adequately controlled. Where this is not practicable, the affected ductwork shall be acoustically lagged to control noise breakout/break-in.

V03.3.1.13. The sound attenuators for Trackway Exhaust Fans, Booster Fans and Tunnel Ventilation fans shall be designed to withstand an airstream of 250°C for a minimum of 2 hour and maintain structural integrity and airtightness. Manufacturers certification of this shall be submitted. Suitable fire rated material like fire rated paint/calcium silicate Board may be used to meet the criteria of BS 476 pt 24.

V03.3.1.14. The sound attenuators shall be delivered with blocked ends to avoid ingress of rubble equipment and shall be checked for damage during delivery to site, before installation and after installation. Where splitters are delivered separately, for site assembly, the absorbent surfaces shall be adequately protected against damage .

V03.3.2. Equipment bases

V03.3.2.1. Floor mounted equipment shall be installed on minimum 200mm high concrete housekeeping pads with a minimum of 150mm further on each side of mountings. Alternatively, equipment may be supported on inverted beams of roof. Vibration isolators shall then be mounted on this concrete pad or inverted beams.

V03.3.3. Plant/Equipment vibration isolation

V03.3.3.1. All rotating or reciprocating equipment shall be mounted on vibration isolation mountings or suspended from vibration isolation hangers.

V03.3.3.2. The Contractor shall be responsible to ensure that there is no rigid connection in whatever form between the isolated equipment and the structure, which will otherwise short-circuit the vibration isolation system and degrade its performance. This includes the necessary co-ordination with other trades by the Contractor.

V03.3.3.3. All isolators shall operate in the linear portion of their load versus deflection curves. Loads versus deflection curves shall be furnished be the Manufacturer, and must be linear over a deflection range of not less than 50% above the design deflection.

V03.3.3.4. All vibration isolator shall have their known undeflected heights or calibration markings so that, after adjustment and when carrying their design loads, the deflections under load can be verified. This permits the determination that the load is within the proper range of the device and that correct degree of vibration isolation is being achieved according to the design.

V03.3.3.5. The static deflection of the isolators at each support point shall not differ from the design objective for the equipment as a whole by more than ±10%.

V03.3.3.6. The ratio of lateral to vertical stiffness for springs shall not be less than 0.9 nor greater than 1.5.

V03.3.3.7. All neoprene mountings shall have hardness of 40 to 65 durometer, after minimum aging of 20 days or corresponding over-aging.

V03.3.3.8. In order to resist corrosion, all vibration isolation mountings and hangers shall be treated as follows:

- ❖ Springs to be neoprene coated or hot-dipped galvanised
- ❖ Wearing hardware to be cadmium plated steel or stainless steel of an appropriate grade
- ❖ All other metal parts to be hot-dipped galvanised

V03.3.3.9. All vibration isolators and associated equipment bases shall whenever possible be the product of a single Manufacturer.

V03.3.3.10. Not used

V03.3.3.11. Limit stop or horizontal thrust restraints shall be provided for all fans.

V03.3.3.12. Vibration control / vibration sensor equipment shall be designed and installed in accordance with the fan Manufacturer’s recommendation.

V03.3.3.13. Spring type isolators

- ❖ Spring type isolators shall be free standing and laterally stable without any housing and complete with 6mm neoprene acoustic friction pads between the base plates and the supports.
- ❖ All mountings shall have levelling bolts that must be rigidly bolted to the equipment

- Spring diameters shall be not less than 80% of the compressed height of the spring at rated load.
- Springs shall a minimum additional travel to solid equal to 50% of the rated deflection

V03.3.3.14. Spring type isolators with limit stops

- Equipment with operating weight different from the installed weight shall be mounted on spring mountings complete with a housing, which shall include vertical limit stops to prevent spring extension when weight is removed
- The installed and operating heights shall be the same
- A minimum clearance of 12mm shall be maintained around restraining bolts so as not to interfere with the spring action
- Limit stops shall be out of contact during normal operations
- Mountings used outside shall be hot-dipped galvanised to BS729

V03.3.3.15. Vibration pads

- All vibration pads shall be neoprene in-shear multi-layer waffle type with steel shims in between waffles

V03.3.3.16. Horizontal thrust restraints

Thrust restraint shall consist of a spring element in series with a neoprene pad. The spring element shall be contained within a steel frame and designed so that it can be preset for thrust at the factory and adjusted in the field to allow for a maximum of 6mm movement at start and stop.

- The assembly shall be furnished with one rod and angle brackets for attachment to both the equipment and ductwork or the equipment and the structure. Horizontal restraints shall be attached at the centre-line of thrust and symmetrically on either side of the unit.

V03.3.4. Selection guide for equipment bases and vibration isolators

V03.3.4.1. Unless otherwise specified, the selection of type equipment base and vibration isolator (mounting/hanger) for differing plant/equipment and on differing floor spans & levels may follow the requirements as indicated in the Selection Guide for Vibration Isolation Table 48 (chapter 47) of the ASHRAE Application Handbook 2007, and the static deflection of the vibration isolator selected shall provide a minimum isolation efficiency of not less than the corresponding values shown in Table 48. However, the Contractor is responsible to ensure the selected vibration isolation system is suitable for his specific plant/equipment and the specific building structure on which the plant/equipment is mounted.

V03.3.4.2. The Contractor shall provide more efficient isolation than those suggested in Table 48 in case if the adjacent occupied space is a noise critical.

V03.3.5. Method of installation

V03.3.5.1. The equipment structural steel or concrete inertia base shall be place in position and supported temporarily by blocks or shims. The machinery shall then be installed on the base and when that is complete, the isolator are to be installed without raising the machine and frame assembly.

V03.3.5.2. After the entire installation is complete and under full operational load, the isolators shall be adjusted such that the load is transferred from the blocks to the isolators. When all isolators are properly adjusted, the blocks or shims will become slightly free and can then be removed.

V03.3.5.3. The springs of vibration isolators shall in general have a loaded working height equal to 1.0 to 1.5 times the outside diameter of the spring and shall be compressed to approx. 50% of their unloaded height.

V03.3.5.4. Where any vibration isolation system permits equipment motion in all directions, provide where necessary additional resilient restraints to flexibly limit the lateral movement of the equipment to 6mm at start and stop.

V03.3.5.5. Prior to start-up, remove all foreign matter underneath the equipment base and verify that there is no short-circuiting of the vibration isolation system.

V03.3.5.6. Electrical circuit connections to isolated equipment shall be looped to allow free motion of isolated equipment.

V03.3.6. Ductwork vibration isolation

V03.3.6.1. Flexible connections shall be provided between the vibrating equipment and the ductwork and shall be made of approved materials such as lead vinyl or similar material of minimum surface density of 5kg/m² and installed such that airflow is not obstructed. The material used must be in compliance with local statutory requirements for fire retardant period.

V03.3.6.2. Unless otherwise specified, all discharge ducts run for a distance of 15m from the connected vibrating equipment, which has a discharge pressure of 1kPa or above shall be isolated from the structure by means of spring hangers. Spring deflections shall be a minimum of 20mm.

V03.3.6.3. In case where fire damper is required, ductwork to be isolated shall be fitted with a flexible joint on the side of the fire damper where the vibration originates.

Section V04: Ductwork

TABLE OF CONTENT

V04.1. General

V04.1.1. The ductwork for the tunnel ventilation system shall consist of circular bellmouth, upper and lower transitions and diffusers at various levels of the fan rooms.

V04.1.2. Ductwork shall withstand 125% of the maximum shut-off pressure difference that can be developed by fans in either forward and reverse direction.

V04.1.3. Ductwork shall withstand an air temperature of 250°C for two hour without structural distortion affecting the airflow path.

V04.1.4. The Contractor shall provide and install all necessary ductwork, control, isolating and balancing dampers, smoke dampers, grilles, and diffusers to form complete air distribution systems.

V04.1.5. All ductwork shall be constructed and erected to present rigid installation free from sway, drumming and movement. Ductwork shall be true-to-size and accurately aligned.

V04.1.6. As far as is practicable, longitudinal seams and joints in adjacent ductwork sections shall be aligned, particularly where permanently visible after installation.

V04.1.7. Perforated rivets shall not be used in the manufacture or erection of ductwork

V04.1.8. The use of self-tapping screws shall be restricted to the completion of side joints in extremely difficult location only.

V04.1.9. Ductwork supports shall be positioned close to dampers, diffusers and all similar equipment., which must not be subjected to distortion, in addition to those hangers and supports generally required for ductwork.

V04.1.10. Allowances shall be made in ductwork construction for instrument and controls connections. Adequate local stiffening shall be incorporated to provide rigid mountings. All instrument and control element installations shall be detailed, constructed and installed by the Contractor. In addition, the Contractor shall install all field control devices whether part of his supply or not.

V04.2. Quality control

V04.2.1. All raw edge of ductwork, lock formed seams, rivets and areas where galvanising has been destroyed shall be cleaned, prepared and painted on all edges and sides with zinc-rich paint to BS 4652 at works. Transit damage shall be repaired on site prior to erection.

V04.2.2. Ductwork materials and construction shall generally comply with the Heating and Ventilating Contractor’s Association (HVCA) specification for sheet metal ductwork – low, medium and high pressure/velocity systems – DW/142 and DW/142 Addendum A, except as otherwise specified.

V04.2.3. Ductwork classification shall be High Pressure, with leakage limit to Class D.

V04.2.4. The Employer’s Representative may accept alternative ductwork construction to SMACNA (Sheet Metal and Air-Conditioning Contractors’ National Association), standard for low pressure and high pressure duct construction if proposed by the Contractor in writing and provided always that such alternative are fully in compliance with this Specification. These alternatives shall not impose any additional contractual and financial liabilities on the

Employer's Representative, and shall be submitted so as not to cause any delay to installation.

V04.3. Technical and installation requirements

V04.3.1. "Ductwork shall be generally fabricated from Galvanized Iron sheet/MS Sheet with high temperature paint of 4 mm minimum sheet thickness.

V04.3.2. Flanges shall be of G I angle. The maximum spacing between flanges is 4m.

V04.3.3. Intermediate stiffeners shall be of 100mm x 100mm x 10mm G.I angle. The maximum spacing between intermediate stiffeners is 1m.

V04.3.4. Angle stiffening shall be welded to the duct by the toe of the leg normal to the duct so that the leg parallel with the duct is away from it and a channel shape is formed.

V04.3.5. Ductwork shall be designed and fabricated in modular sections. The maximum dimensions of these modular sections shall be suitable for access through the designated access hatches and doors.

V04.3.6. The ductwork sections shall be fabricated in modular form in workshop where all welding, surface treatment, alignment are to be completed. Installation on site shall only involve positioning and bolting of the ductwork sections and the final painting.

V04.3.7. Flanges shall be bolted and sealed with 6mm thick silicon-based gasket material covering the full face and suitable for emergency operation with air flow temperature of 250°C for two hour.

V04.3.8. Each bolt shall be fabricated from stainless steel / GI, not less than 12mm diameter and be complete with a nut, 2 plain washers and a lockwasher. Spacing of bolts on flanges shall not exceed 200mm.

V04.3.9. The paint shall be durable for a period of ten years at normal operation and shall be capable of withstanding a temperature of 250°C for two hour without emitting smoke or toxic fumes.

V04.3.10. The inlet circular bellmouth for fan intake shall have a radius to width ration not less than 0.15 to minimise pressure loss of intake during normal operation.

V04.3.11. Materials used for ductwork construction shall be free from blisters, pits and imperfections in coating.

V04.3.12. Details of the types of seam and cross-joints proposed shall be submitted before manufacture. Selections shall be suitable for the ductwork system classification.

V04.3.13. All seams shall incorporate sealant and be tightly formed. Edge sealant shall not be used.

V04.3.14. Sealant shall be used between sheet and flange section in cross-joint assembles.

V04.3.15. Flanged joints shall be located at all plant and equipment items, at structural walls and floor slabs and elsewhere as specified for disconnection purposes.

V04.3.16. Joint corners and junction details shall be mutually compatible with longitudinal seam used.

V04.3.17. Tie rod stiffeners for rectangular and flat oval ducts shall have internal nuts and external nuts, metal and compressible washers, unless otherwise specified.

V04.3.18. All bends shall be ‘easy’ type (to minimise pressure loss) except where specified otherwise.

V04.3.19. Arrangement and supports

V04.3.19.1. All anchors in the concrete shall be stainless steel/GIand the anchoring system shall be the product of one manufacturer. Anchors shall be installed in conformance with the

manufacturer’s instruction. Anchors shall have a minimum diameter of 12mm and spaced at not more than 200mm.

V04.3.19.2. Flange connections with concrete and between ductwork shall be fitted with gaskets materials to ensure airtightness. The gaskets shall withstand a temperature of 250°C for two hour without emitting hazardous gases.

V04.3.19.3. Flange connection between metal duct and concrete shall be made with a mating flange. The Contractor shall check the setting out positions of the cast-in items and satisfy himself the positions are acceptable.

V04.3.19.4. A proprietary support system may be used. Full details shall be submitted for approval before ordering.

V04.3.19.5. Duct hangers shall be painted as specified.

V04.3.19.6. Vertical ducts shall be supported off floor slab or by purpose-made brackets fixed to the structure. Details shall be submitted before manufacture.

V04.3.20. Access doors/panels

V04.3.20.1. Access doors shall have adequate warning sign and safety procedures to ensure safety of personnel.

V04.3.20.2. Access doors shall be provided for interior maintenance of the ductwork or inspection of the equipment. Doors shall have a clear opening of not less than 600mm x 600mm. Doors shall at least be provided with Suitable numbers of Hinges and latches. Latches shall be operable from both side of the door. Doors shall be reinforced with angles and set in an angle frame. Doors shall be sealed with 6mm thick gasket materials that will withstand an airflow temperature of 250°C for two hour.

V04.3.20.3. Access doors shall be provided, at least one for each fan in a convenient location to allow entry as well as a quickly detachable temporary floor or platform where required, to enable reasonable access for fan blades adjustment.

V04.3.20.4. Access panels shall be installed to allow visual inspection of operating equipment. They shall be installed where required for inspection of equipment. Panels shall be 400mm x 400mm minimum size. They shall be constructed equal to access doors except that only two hinges and latches are required. Latches shall be operable from the outside only.

V04.3.20.5. All access panels shall be leakage tested to DW144 standard and to the test pressure of the ductwork.

V04.3.21. Test ports

V04.3.21.1. Test ports for air measurements shall be provided in the ductwork adjacent to each fan. There shall be two test ports at each location positioned 90° apart. Where possible, one pair of ports shall be located downstream of the equipment and one pair upstream of the equipment. A test port shall consist of a short 60mm pipe socket welded to the hole in the ductwork. Sockets shall have a screwed pipe plug.

V04.3.22. Wire guards

V04.3.22.1. Hot-dipped galvanised wire guards made of minimum 1.6mm diameter wire shall be fixed to the inlet and discharge bellmouth of fans and across vertical openings of silencers and dampers for safety of maintenance personnel in the air plenum. The guards shall be designed to withstand a weight of 200kg.

V04.3.23. Flexible connectors

V04.3.23.1. Flexible connectors shall be provided between all fan units and the associated ductwork to reduce transmission of vibration to adjacent elements.

V04.3.23.2. Each side of factory assembled flexible material shall mechanically attached with 75mm wide galvanised steel edging.

V04.3.23.3. Flexible materials shall be lead with vinyl or fibreglass cloth, with fire resistant neoprene coating on both sides and suitable for continuous operating temperature of 250°C for a minimum of two hour duration.

V04.3.23.4. The width of the flexible portion shall be 200mm as required for installation conditions and to allow freedom of movement without unnecessary slack.

V04.3.23.5. Flexible materials shall be UL listed and meet all requirement of NFPA standard 90A and local codes and regulations. Other relevant and applicable British Standard shall apply.

V04.3.23.6. Fabric part of flexible connectors shall not be painted.

V04.3.23.7. All air ductwork, associated fittings and components shall be well sealed to avoid noise from leakage and internally free from new edges and projections.

V04.3.23.8. Flexible connectors shall be installed in accordance with SMACNA duct construction standard as appropriate.

V04.3.23.9. Flexible connectors shall be protected with material such as baffle plat to act against the fluctuation air pressures and stresses due to the operation of the ventilation fans.

V04.3.24. Turing vanes

V04.3.24.1. Even if not shown on the drawings, turning vanes shall be provided in each mixing chamber or location of 90° turn for both concrete under platform exhaust shaft and tunnel ventilation shaft.

V04.3.24.2. Turning vanes shall withstand twice aerodynamic force due to airflow that can be developed by the fans. They shall be suitable for supporting their own weight.

V04.3.24.3. Blanking plates and sealing plates shall be provided for a complete installation.

V04.3.24.4. Turning vanes, supports, stiffeners, flanges, and welded fillers shall be fabricated from galvanised mild steel, with all bolts, nuts and washers of galvanised or stainless steel.

V04.3.24.5. Vanes shall be of continuous seam welded construction, except for stiffening ribs, which may be stitch welded.

V04.3.24.6. Surface welds shall be ground smooth and flush with the parent metal.

V04.3.24.7. Vane edges and tips shall be rounded with a minimum radius for smooth airflow. Tips welds shall be ground to a smooth continuous radius.

V04.3.24.8. All materials shall be suitably treated to prevent corrosion. Cut edges shall be cleaned and treated with a zinc rich primer and the entire assembly painted as described.

V04.3.25. Air grilles

V04.3.25.1. Single deflection bar type grilles shall be provided for the underplatform and overtrack exhaust system.

V04.3.25.2. Air grilles complete with dampers shall be made of aluminium or galvanised steel, rated for operation at 250°C for a period of a minimum of two hour.

V04.3.25.3. The dampers shall be adjusted to control airflow to achieve an even air distribution along the underplatform exhaust shaft.

V04.3.25.4. Dampers shall be of the sliding plate type, with facility to securely lock the blade in place following system balancing. Alternatively, the dampers shall be of the opposed blade type with concealed adjustment mechanism that can be securely locked following system balancing.

V04.3.25.5. All bolts, nuts and washers for fixing shall be fabricated with stainless steel/GI.

V04.3.26. Painting and identification

V04.3.26.1. All pipes, ferrous supports, gantries, brackets and steelwork in the Contract works other than those indicated to be left self finished such as stainless steel, anodised aluminium etc. shall be painted in accordance with the section of the specification. All painted surfaces are to receive at least one primer coat and two coats of the finishing colour unless otherwise specified.

V04.3.26.2. The Contractor shall obtain from the supplier of any paint or similar product detailed instructions for the use of that product, specific to the conditions found on the Contract. These shall include details of storage, preparation of steelwork, application method and conditions, overcoating and any other relevant points.

V04.3.26.3. The Contractor shall comply with the Manufacturer's instructions for the use of any product, unless these are in conflict with the requirements of this specification. Areas of conflict shall be brought to the attention of the Employer's Representative.

V04.3.26.4. Pipes and ducts, whether concealed or normally visible, must be painted either in the appropriate colour code or as required by the Employer's Representative and appropriate colour code bands.

V04.3.26.5. Ferrous metals shall be primed before delivery to site. After welding, drilling and fabrication, but before installation, the surfaces shall be prepared, thoroughly wire brushed to remove all scale and loose rust and painted with one coat of zinc rich primer. After installation the primer shall be touched up, one under-coat and two finishing coats of oil paint of a colour selected by the Employer's Representative shall be applied.

V04.3.26.6. Galvanised iron surfaces shall be primed using an etch primer suitable for the surface. Painting and preparation procedures shall be as for other ferrous surfaces.

V04.3.26.7. The colour(s) of paint(s) shall be selected from the range contained in BS 4800 as instructed.

V04.3.26.8. All distribution services shall be colour coded and provided with symbols for identification purposes. Identification coding for ductwork, including thermal insulation, shall be in accordance with HVAC Specification DW/144.

V04.3.26.9. Pipework or ductwork shall be identified by bands at least 25mm wide and colour triangles of at least 150mm side. The bands or triangles shall be spaced and located to permit ready identification of the services particularly adjacent to equipment positions and at service junctions and wall penetrations.

V04.3.26.10. In addition to colour bands or triangles all pipework and ductwork in plant rooms and services areas whether insulated or not shall be legibly marked with black or white letters and triangles to show the type of service and the direction of fluid flow.

Services shall be shown as follows:

Tunnel Ventilation	TV
Draught Relief	TV-DR
Underplatform (Overtrackway) Exhaust	UPE (OTE)

DATA SHEET FOR FIRE RATED DUCT MATERIAL AND DUCT WORK	
Duct Material	As per Specifications
Operational Temperature	Smoke Extraction @ 250 °C for 2 Hours rating
Duct Performance	As Per DW/144, SMACNA Air Duct Leakage Manual
Duct Material	Fire Rated To Comply With BS – 476 Part 24
Reference Standard	Tested in accordance with BS 476 Part 24
Flame And Fire Spread	DETR Building Regulations – Fire Safety Class O
Fire Duct Work	Manufactured to HVCA Standard – DW /144, NFPA 90A
Function	The Fire Rated Ductwork Shall Have The Same Fire Rating As The Fire Compartment Through Which It Passes
Duct Material	Resistant to Water Impingement From Any Sprinkler System
Duct Work	Installed in accordance With DW/144, NFPA 90A (2002)
Impact Resistance	SMACNA – HVAC Duct Construction Standards
Stability And Integrity	Must Retain at least 75% of its overall Cross Sectional Area (BS – 476 Part 24 (1987) For Two Hour)
Leak Test	HVCA Specification DW/144, SMACNA Air Duct Leakage Manual
Gaskets / Sealant	Flame Proof
Duct Work Seals	As Per BS – 476 Part 24

Gauge of Sheet (Min)		As per clause V0-4.3.1 of specification
Transverse Seams At Joint		Companion Angles Flanged Joints (40 x 40 x 6mm)
Min. Bracing Angle Size And Max. Longitudinal Spacing From Joints / Intermediate reinforcement (mm)		100 x 100 x 10 mm @ 100 mm Spacing
Joint Strength		Should With Stand 1.5 Times the Operating Pressure Without Deformation Or Failure
Duct Accessories	For Joints	Hexagonal Nuts – Bolts / Washers SS-304
	Rivets	SS-304
	Gaskets	Sizes matching the flanges, temperature rating of 250^0C for 2 hour
	Screws	Self Tapping Screws Will Not Be Used
Support Arrangement		As Per SMACNA – 1995
Support From Wall / Ceiling		Anchor Fastener Of Required Rating Not Less Than 2.5 Times the Load
Paint		Flanges And Supports Treated For Corrosion And Painted With Zinc Rich Paint Of Approved Quality
Flexible Connection circular Spigots		Fire Proof Material To Be Screwed Or Clip Band With Adjustable Screw Or Toggle Fitting
Flexible Connection Rectangular Ducts		Fire Proof Material To Be Flanged And Bolted With Backing Flat Or Bolted To Mating Flange With Backing Flat
Flexible Connection		150 mm Length Between Two Faces (Minimum)

Section V 05 Tunnel Booster Fans

TABLE OF CONTENT

V05.1 GENERAL

V05.1.1 The Work of this attachment consists of furnishing, installing and testing of tunnel ventilation equipment complete with all required accessories, including axial booster fan-motor units, sound attenuators, hangers, supports, and associated work, hereinafter specified or otherwise required for a complete and fully operable system.

V05.1.2 The following definitions apply to the Work of this Section:

V05.1.3 Fan: The terms fan, jet fan, tunnel booster fan, and booster fan assembly are synonymous and are deemed to mean a booster fan complete with sound attenuators and a directly-connected reversible motor.

V05.1.4 Forward Flow: Airflow generated by the fan in the direction of the fan impeller to the fan motor.

V05.1.5 Reverse Flow: Airflow generated by the fan in the direction of the fan motor to the fan impeller.

V05.1.6 Pitch: The angle formed by the chord line of a fan blade root cross-section and a line parallel to the direction of rotation.

V05.1.7 Manufacturer's Representative: A representative from the firm of manufacturer for each and every category of equipment furnished under this Section.

V05.2 QUALITY ASSURANCE (Referance standard)

V05.2.1 The following Codes, Regulations, Reference Standards and Specifications apply to the Work of this Section.

V05.2.1.1 Anti-Friction Bearing Manufacturer's Association (AFBMA):

V05.2.1.1.1 Load Ratings and Fatigue Life for Ball Bearings

V05.2.1.1.2 Load Ratings and Fatigue Life for Roller Bearings

V05.2.1.2 Air Movement Control Association Inc. (AMCA):

V05.2.1.2.1 Laboratory Methods of Testing Fans for Rating

V05.2.1.2.2 Test Code for Sound Rating of Air Moving Devices

V05.2.1.2.3 Method for Publishing Sound Ratings

V05.2.1.3 American National Standards Institute (ANSI):

V05.2.1.3.1 Surface Texture, Surface Roughness, Waviness and Lay, Part 1.

V05.2.1.3.2 C1 Specification of General Requirements of a Quality Program

V05.2.1.3.3 S12.36 Survey Methods for Determination of Sound Power Levels of Noise Sources

V05.2.1.3.4 Z49.1 Safety in Welding and Cutting

V05.2.1.3.5 Z55.1 Grey Finishes for Industrial Apparatus and Equipment

V05.2.1.4 American Society for Testing and Materials (ASTM):

V05.2.1.4.1 A 36 Structural Steel

V05.2.1.4.2 A 123 Zinc (Hot-Galvanised) Coatings on Products Fabricated from Rolled, Pressed and forged Steel Shapes, Plates, Bars, and Strip

V05.2.1.4.3 A 193 Alloy-Steel and Stainless Steel bolting Materials for High-Temperature Service

V05.2.1.4.4 A 194 Carbon and Alloy Steel Nuts for Bolts for High-Pressure and High-Temperature Service

V05.2.1.4.5 A 239 Locating the Thinnest Spot in Zinc (Galvanised) Coating on Iron or Steel Articles by the Preece Test (Copper Sulfate Dip).

V05.2.1.4.6 A 276 Stainless and Heat-Resisting Steel Bars and Shapes

V05.2.1.4.7 A 666 Authentic Stainless Steel, Sheet, Strip, Plate, and Flat Bar for Structural Applications

V05.2.1.4.8 E 84 Surface Burning Characteristics of Building Materials

V05.2.1.4.9 E 94 Radiographic Testing

V05.2.1.4.10 E 155 Reference Radiographs for Inspection of Aluminium and Magnesium Castings

V05.2.1.5 American Welding Society (AWS):

V05.2.1.5.1 D1.1 Structural Welding Code, Steel

V05.2.1.5.2 D1.3 Structural Welding Code, Sheet Steel

V05.2.1.6 Federal Specifications (FS):

V05.2.1.6.1 TT-P-645A Primer, Paint, Zinc Chromate, Alkyd Type

V05.2.1.6.2 Institute of Electrical and Electronic Employer's Representatives (IEEE):

V05.2.1.6.3 85 Standard Test Procedure for Airborne Sound Measurements on Rotating Electric Machinery

V05.2.1.6.4 112 Standard Test Procedure for Polyphase Induction Motors and Generators

V05.2.1.7 Military Specifications (Mil. Spec.):

V05.2.1.7.1 DOD-P-21035A Paint, High Zinc-Dust Content, Galvanising Repair (Metric)

V05.2.1.8 National Electrical Manufacturers Association (NEMA):

V05.2.1.8.1 MG1 Motors and Generators

V05.2.1.8.2 MG1-12.54 Efficiency

V05.2.1.9 Steel Structures Painting Council (SSPC):

V05.2.1.9.1 SP-1 Solvent Cleaning

V05.2.1.9.2 SP-2 Hand Tool Cleaning

V05.2.1.9.3 SP-3 Power Tool Cleaning

V05.2.1.9.4 SP-6 Commercial Blast Cleaning

V05.2.1.9.5 PA-1 Shop, Field, and Maintenance and Painting

V05.2.1.9.6 PA-2 Method for Measurement of Dry Paint Thickness with Magnetic Gauge

V05.2.1.10 International Standards Organisation (ISO):

V05.2.2 Manufacturer's Qualifications

V05.2.2.1 Furnish booster fan assemblies supplied by a single manufacturing firm that is regularly engaged in the production of booster fans of the type specified herein.

V05.2.2.2 Submit documentation by the manufacturer that booster fans, of the capacity (thrust and exit jet velocity) not less than that to be furnished under this Section have been satisfactorily used in transit tunnel projects for at least five years.

V05.2.3 Submittals

V05. 2.3.1 Submit the following to the Employer’s representative for review and obtain a notice of no objection:

V05.2.3.2 Shop Drawings

V05.2.3.2.1 Submit dimensioned drawings of tunnel ventilation fans showing sound attenuator assembly layout, supports and other appurtenances required for installation. Show on shop drawings, point loads at each support point including summary of dead loads, axial loads and thrust loads, and complete installation details.

V05.2.3.3 Submit design calculations for the fan structural supports.

V05.2.3.4 Submit a tabulation showing the thrust, exit jet velocity and sound power level of the booster fan assembly at the design point blade angle setting and at three additional settings, in 2 degree increment, above and below the design point. Derive the data from the actual fan assembly performance tests. Require the fan manufacturer to identify the possibility of fan stalling if it exists within the fan performance region covered by 15% above and below the design condition as specified.

V05.2.3.5 Submit motor performance curves that are either derived from actual performance tests or from analytical data. Submit separate performance curves for the motor rotation in forward and reverse directions.

V05.2.3.6 Submit shop drawings and the test procedures for the pre-production units as a package.

V05.2.3.7 Submit narrative test reports for all factory and field tests. Include the raw data as recorded during each test.

V05.2.3.8 Certificates of Compliance

V05.2.3.8.1 Submit certificate of compliance that the design and fabrication of various components of the tunnel ventilation system meet he requirement of the Contract.

V05.2.3.8.2 Submit certificate of compliance that the booster fan assemblies meet the requirement of operation at elevated temperature of 250 degree C for two hour.

V05.2.3.9 Include data substantiating that materials comply with the requirements of the various standards as specified.

V05.3 TECHNICAL & INSTALLATION REQUIREMENTS

V05.3.1 General

V05.3.1.1 In selecting equipment, provide interchangeability of parts.

V05.3.1.2 In selecting booster fan assemblies, ensure that the operating weight and axial thrust generated by fan on supports do not exceed the maximum acceptable limit indicated by the Contractors calculations.

V05.3.1.3 Furnish booster fan assemblies of a single manufacturer and like components furnished by a single supplier.

V05.3.2 Operating Environment:

V05.3.2.1 Normal Operation - Construct the entire fan-motor-sound attenuator assembly such that it withstands the environmental changes caused by the passing of subway trains.

V05.3.2.2 Emergency Operation - Construct the entire fan-motor-sound attenuator assembly including hangers, supports, emergency stop button and cables etc., such that any of the components does not suffer mechanical, electrical or structural failure when operating at full capacity in an ambient air temperature of at least 250 degree C for a minimum period of two hour.

V05.3.3 Fans

V05.3.3.1 General Requirements

V05.3.3.1.1 Furnish fans of the axial-flow type, direct-driven by internally mounted single speed motors which are capable of delivering air in both the forward and reverse directions of airflow when the motor rotation is reversed. Permanently mark the forward direction of airflow in conspicuous location on the exterior of the fan housing.

V05.3.3.2 Performance Requirements

V05.3.3.2.1 Not used

V05.3.3.2.2 Furnish fans capable of satisfactorily withstanding the effect of all stresses and loads under starting, operating and reversing conditions.

V05.3.3.2.3 Provide fans capable of developing thrust and exit jet velocity, in either direction of motor rotation

V05.3.3.2.4 Provide fans capable of reversing airflow in sixty seconds or less, from full speed forward to full speed reverse or vice versa with a maximum de-energised period of 30 seconds between reversals. The capability of reversing airflow direction at least two times (one cold and two hot starts) during any one hour of continuous operation with 250 degree C air flowing through the fan is required.

V05.3.3.2.5 Not used.

V05.3.3.2.6 Furnish booster fan assembly having vibrations that do not exceed BV 4 limit as per ISO 14694.

V05.3.3.3 Fan Components and Materials

V05.3.3.3.1 Fabricate impeller hub and blades of aluminium-alloy casting or other material suitable for the specified performance and environment.

V05.3.3.3.2 Fasten impeller to the motor shaft by means of positive locking devices that are fully effective for both directions of airflow, for all blade angle settings and for all conditions of operation specified.

V05.3.3.3.3 Design and construct impeller to withstand stresses and loads created by overspeed testing to 125 percent of the nominal operating speed.

V05.3.3.3.4 Design and construct impeller and hub suchthat the pitch of blades can be manually adjustable without removing impeller. Provide the blades and hubs with index marks that show the design operating blade setting and a minimum of three increments of stagger angle larger and three increments smaller, than the design operating blade setting. Provide stops on the hub to preventoverload of the motor. As a substitute for the index marks, eachtype of fan for each station may have one metal template to facilitate accurate settings of blade angles.

V05.3.3.3.5 Fabricate fan housing, motor mounts and supports and housing supports of hot rolled steel/ mild steel . Provide fan housing of continuously welded construction and of thickness not less than No. 8 United States Standard Gage (USSG). Ascertain that welds located in air stream are ground smooth.

V05.3.3.3.6 Form fan housing to a true-round, concentric, cylindrical shape providing uniform clearance between the tips of the impeller blades and the housing. Provide adequate clearance between blade tips and the housing at all points to allow for expansion and construction over a temperature range from 0 degree C to 250 degree C without developing interference. Indicate on shop drawings the clearance at 0 degree C to 250 degree C, as well as at any point of minimum clearance in between.

V05.3.3.3.7 Provide end flanges for the housing of the same thickness as the housing. Flanges may be rolled integrally or continuously welded to the outer periphery of the fan housing. Provide flanges of sufficient width having punched or drilled holes to allow sound attenuators to be rigidly bolted to the housing.

V05.3.3.3.8 Design and construct motor supports to make the motor axis and fan housing axis concentric. Provide motor mounts and motor supports in sufficient number and of the design to support the entire weight of the impeller and the motor, and the loads developed by the fan operation.

V05.3.3.3.9 Not used

V05.3.3.3.10 Provide fan housings of sufficient length to totally enclose the fan impeller and motor within the housing.

V05.3.3.3.11 Make the ends of the fan housing straight and smooth, suitable to receive sound attenuators at both ends. Provide connection between fan and sound attenuators that facilitates easy assembly and disassembly of booster fan and sound attenuators in the field.

V05.3.3.3.12 Provide lifting lugs of steel construction, welded on the exterior of fan housing and sound attenuators. Provide lifting lugs in sufficient number to facilitate future on-site installation and removal of the fan and sound attenuators.

V05.3.4 Motors

V05.3.4.1. General Requirements

V05.3.4.1.1 Furnish motors for all tunnel ventilation fans supplied by a single manufacturer.

V05.3.4.1.2 Provide motors that confirm to applicable ANSI, IEEE and NEMA or approved equivalent ISO standards or IEC standard and are of NEMA Design B or relevant ISO standard or IEC standard, designed for continuous operation for a minimum period of two hour in an ambient temperature of at least 250 degree C.

V05.3.4.1.3 Do not furnish motors with a thermal protector integral with the motor.

V05.3.4.1.4 Provide motors of the totally enclosed, high efficiency, air-over all cast iron or high grade silicone steel frame, induction type. Wire motors for full voltage starting and reversing.

V05.3.4.2 Motor Performance Requirements

V05.3.4.2.1 Provide motors capable of accelerating the fan impeller from stand still to the rated rotational speed in not more than 15 seconds, when connected to terminal voltage of 75 percent of the nominal supply voltage.

V05.3.4.2.2 Provide motors capable of starting, reversing and operating continuously, under full load conditions, for a minimum period of two hour in ambient temperature of at least 250 degree C in either the forward or the reverse mode of operation.

V05.3.4.2.3 Provide motors capable of reversing in sixty seconds or less, from full speed forward to full speed reverse and vice versa with a de-energised period of 30 seconds maximum between reversals. The capability of performing a minimum two reversals during a sixty minute period with 250 degree C air flowing through the fan is required.

V05.3.4.2.4 Rate motors in accordance with NEMA/IEC or Equivalent International Standards for the locked-rotor input (Kilovolt-amperes per kilowatt) required to meet the indicated acceleration performance. Provide motors with a minimum of Class H insulation and rated for Class F temperature rise, when tested at service factor load as a minimum requirement.

V05.3.4.2.5 Provide motors capable of operating continuously at rated torque at any terminal voltage between 85 percent and 110 percent of the nominal supply voltage.

V05.3.4.2 Motor Components and Construction

V05.3.4.2.1 Provide motor shaft of steel construction, designed to support and drive fan impeller under all specified operating conditions. Provide each motor with lifting lugs in sufficient numbers.

V05.3.4.2.2 Equip motors with anti-condensation heaters to prevent condensation of moisture in the motor windings. Energise heaters when the motor is not operating, and de-energise whenever the motor is in operation. Terminate heater leads in the common terminal box mounted on the exterior of the fan housing.

V05.3.4.2.3 Provide motor leads of insulated copper, wired to an oversized weatherproof conduit box mounted on the exterior of the fan housing. provide conduit box with screw-type or bolt down pressure terminals and exterior mounting lugs. Protect lead wires from airstream by enclosing them in an air-tight, high tensile strength, seamless metal rigid conduit.

V05.3.4.2.4 Design and construct motor bearings for maximum radial and thrust loads anticipated during starting, operating and reversing conditions. Furnish bearings having a minimum L-10 life rating equal to 40,000 hours as defined by the Anti-Friction Bearing Manufacturers' Associations (AFBMA)/ISO, which is an average bearing life of approximately 200,000 V05.3.4.2.5 Bring lubrication lines from motor bearings to the exterior of the fan housing and terminate in straight lubrication fittings. Terminate grease release lines, if used, in spring loaded relief fittings. Provide grease fittings with covers to exclude water and dust. Select bearing lubricant which is capable of providing the lubrication properties specified by the bearing manufacturer under conditions of operation for two hour in ambient air at a temperature of 250 degree C.

V05.3.4.2.6 Fabricate lubrication lines for motor bearings of high strength, seamless stainless steel/ copper tubing without kinks or sharp bends. Secure lubrication lines rigidly, to the housing to prevent vibration of the lines and the leakage of air.

V05.3.4.2.7 Furnish motor bearing with a vibration monitoring system, complete with velocity pick-up transducer, monitor and connection cable. Furnish the monitoring system that is to trigger remote alarms for two levels of vibrations: "Alert" and "Alarm." The alert level is to trigger an alarm when general wear and minor defects have increased motor vibration to a level where maintenance is needed. The alarm level is to safeguard the motor against dangerous vibration caused by damage or sudden out of balance. Provide measuring range that includes 2 to 20 millimetres per second RMS for alert and 2 to 60 millimetres per second RMS for alarm. Encase monitor in a dust-proof water-tight enclosure. Wire the monitoring device to the common terminal box mounted on the exterior of the fan housing.

V05.3.5 Sound Attenuators

V05.3.5.1 General Requirements

V05.3.5.1.1 Furnish sound attenuators for tunnel ventilation fans selected by the fan manufacturer, to meet all operating conditions specified.

V05.3.5.1.2 Provide cylindrical (tubular) sound attenuators one mounted directly on each end of the fan housing. Match the inside diameter of sound attenuator to the inside diameter of fan. Provide inner bullet if required, of aerodynamic design. Match the exterior diameter of the bullet to the diameter of motor and hub.

V05.3.5.2 Performance Requirements

V05.3.5.2.1 Furnish sound attenuator-fan-sound attenuator assemblies that do not exceed the acceptable maximum sound power levels for tunnel environment.

V05.3.5.2.2 The sound power rating is composite of the sound generated by the fan-motor unit and the dynamic insertion losses achieved by sound attenuators. Therefore, require the fan manufacturer to select sound attenuators to meet the requirements.

V05.3.5.3 Sound Attenuator Construction

V05.3.5.3.1 Select the materials and methods used to fabricate sound attenuators such that they be operational for minimum period of two hour in ambient air temperature of at least 250 degree C without any mechanical or a structural failure.

V05.3.5.3.2 Fabricate the exterior casing of not less than No. 18 United States Standard Gage (USSG), hot dipped galvanised steel, internally lined with inorganic mineral wool or glass fibre acoustic in fill covered with not less than No. 22 USSG stainless steel perforated sheets.

V05.3.5.3.3 Provide drain hole of 12 mm diameter minimum in the exterior cashing of each sound attenuator, to drain water that may enter into fan assembly during tunnel washing operations.

V05.3.5.3.4 Design support system to facilitate easy dismantling and reinstallation of fan or sound attenuators as required for maintenance.

V05.3.5.3.5 Fabricate fan supports of galvanised steel not less than 10 mm thick. Weld supports to the fan housing and cross brace to provide rigidity.

V05.3.5.3.6 Design supports suitable for the existing provisions in the field for mounting the supports and the space constraints.

V05.3.5.3.7 Furnish all bolts, nuts, washers and lock washers of stainless steel AISI Type 316. Furnish bolts that are consistent with the existing tunnel inserts.

V05.3.5.3.8 Provide lifting lugs or eyes, in sufficient numbers, and permanently weld to fan housing.

V05.3.5.4 Nameplates

V05.3.5.4.1 Furnish nameplates for each fan assembly. On each nameplate, show the name and address of the fan manufacturer, the Contractor's name and address, serial number of the fan, the maximum safe rotational speed of the fan in revolutions per minute and the design operating conditions of the fan. Rivet or screw nameplates to the fan houses.

V05.3.5.4.2 Furnish two identical nameplates for each motor. On each nameplate, show the name and address of the motor manufacturer, the motor model number and serial number, motor speed in revolutions per minute, nominal kilowatt, electrical characteristics (voltage, phase, frequency); no-load, full-load and locked-rotor currents, NEMA code-letter designation, NEMA frame size, service factor, rating of space heater and the terminal connection chart for the motor. Securely fasten one of the two nameplates to the motor housing; rivet or screw the other to the fan housing adjacent to the fan nameplates.

V05.3.5.4.3 Fabricate all nameplates of stainless steel. Permanently mark the specified data on the nameplates.

V05.3.7 NOT APPLICABLE.

V05.3.8 Painting And Finishing

V05.3.8.1 Provide fan housings, attenuator outside casings, supports and all other steel components either hot dipped or an electro-deposited zinc coating meeting to GS165 standard or equivalent.

V05.3.9 Shop Tests

V05.3.9.1 General Requirements

V05.3.9.1.1 Provide test facility at the fan manufacturer's place or at a testing laboratory which is suitable for all tests specified. The motor test may be performed at the place of the manufacture by the motor manufacturer.

V05.3.9.1.2 Submit all testing standards and procedures for approval by the Authority prior to proceeding with any of the tests.

V05.3.9.1.3 Notify the Authority in writing, of all shop test dates not less than 30 days prior to the test so that the Authority may witness the test.

V05.3.9.1.4 Submit for approval by the Authority the results of the pre-production model fan assembly tests specified. The manufacture of fan assemblies to be procured under this Contract may commence only after the Authority has approved the shop test results for the pre-production booster fan assembly.

V05.3.9.2 Motor Tests

V05.3.9.2.1 Test each motor in accordance with the procedures specified in ANSI/IEEE publication 112.

V05.3.9.2.2 Record test data for the performance curves continuously at the rated voltages and frequency of the motor over the speed range from standstill to rated rotational speed.

V05.3.9.2.3 Only those motors for which test reports and performance curves have been approved by the Authority may be assembled into fan-motorunits.

V05.3.9.3 Fan Tests-General

V05.3.9.3.1 Spin Test-Balance atleast one impeller statically and dynamically at the rated operating speed before spin-testing. Spin test atleast one of impeller at 125 percent of design rotational speed for a period of not less than three minutes. Examine impellers for loose blades and other damages. Replace defective parts and repeat the spin test before further testing.

V05.3.9.3.2 Vibration test - Check atleast one fan for obviously rough operation. Replace defective bearings and recheck fan operation. Test each fan for vibration, measured in two radial planes 90 degrees apart (front and rear), and in the axial direction. Compare the measured vibration levelswith the acceptable vibration limits specified. If the measured vibration exceeds the specified limits, determine the cause(s), correct it and then retest the fan.

V05.3.9.4 Pre-Production Model Fan Tests

V05.3.9.4.1 Prior to commencement of manufacture of booster fans to be procured under this Contract, test as specified in the following paragraphs one pre-production model sound attenuator-fan-motor-sound attenuator assembly unit that has successfully completed the preceding tests.

V05.3.9.4.2 Run-in Test - Operate the pre-production booster fan assembly continuously for 8 hours;4 hours in each direction of motor rotation.

V05.3.9.4.3 Performance Test - Test the pre-production booster fan assembly for performance in accordance with the requirement of ACMA 210/ASHRAE 51/ISO 13350. For measurement of thrust developed, test booster fan assembly in accordance with the requirements of ISO/TC 117 WG6/ISO 13350. Test the booster fan assembly in forward and reverse directions of airflow to determine the thrust developed, airflow, exit jet velocity and motorbrake kilowatt (or input power). Change fan-blade angle and repeat test as required until the specified requirements are satisfied.

V05.3.9.4.4 Noise Test - Test the pre-production booster fan assembly in accordance with the requirements of ANSI S12,36 / ISO 13350/ DIN 45635/ ISO 3741 to obtain sound power data at eight-octave band centre frequencies from 63 hertz to 8000 hertz, in each direction of airflow. Present measured data for each octave band (dB re: 10-12 watts) and in the A-weighing (dBA).

V05.3.9.4.5 Acceptance - The pre-production booster fan assembly which has satisfactorily passed all specified tests will be accepted by the Authority as part of the Procurement under this Contract, provided the booster fan assembly, after installation in the field, is operational in accordance with the specified requirements.

V05.3.10 Installation

V05.3.10.1 Install booster fan assemblies in the space provided in such a manner as to readily serviceable. Verify existing in sets and other installation provisions prior to fabrication of hangers and supports. Additional metallic chain shall be provided as a support for hanging of Tunnel Booster fan.

V05.3.11 Field Tests

V05.3.11.1 General Requirements

V05.3.11.1.1 Perform all tests in the presence of the Authority.

V05.3.11.1.2 Furnish all field test instruments. The Contractor may remove test instruments only after field testing is completed.

V05.3.11.1.3 Provide labour, materials and appurtenances required to complete the specified field tests.

V05.3.11.1.4 Submit all testing standards and procedures for approval prior to proceeding with any of the tests.

V05.3.11.2 Vibration Tests

V05.3.11.2.1 Check fans for obviously rough operation. Replace defective bearings and recheck fan operation.

V05.3.11.2.2 Measure amplitude and frequency of radial and axial vibration levels, and check for conformity to the specified acceptable vibration levels. For a booster fan assembly whose vibration level exceeds the specified limit, balance impeller as required and remeasure vibration level until the specified requirement is met.

V05.3.11.3 Run-in Test

V05.3.11.3.1 Demonstrate that fans are operational in both directions of airflow.

V05.3.11.3.2 Operate each fan continuously for one hour in forward direction of airflow, de-energise for 30 seconds and then re-energise to operate in reverse direction of airflow for one hour.

V05.3.11.3.3 Measure and record for each motor individually, the motor starting current, running current, starting voltage, full load voltage and power factor for motor rotation in each direction.

V05.3.11.3.4 Measure and record running current and full load voltage in each direction with all fans in operation.

V05.3.11.4 Performance Test

V05.3.11.4.1 Test each booster fan for the actual "in-tunnel" performance.

V05.3.11.4.2 Measure the exit jet velocity and air volume generated by the booster fan assembly in each direction of airflow. Based on the measured value of velocity and volume, calculate the thrust developed by the fan.

V05.3.11.4.3 If the calculated thrust is at least 95% of, or more than the specified value, no further testing is required.

V05.3.11.4.4 If the calculated thrust is less than 95% of the specified value, adjust the fan blade angle to increase the airflow; and remeasure the exit jet velocity and air volume until the calculated thrust is at least 95% of the specified value.

V05.3.12 Replacement Materials

V05.3.12.1 ~~Furnish two fan assemblies as spare. Design and construct each spare booster fan assembly to make it identical to the booster fan assemblies being installed as part of the tunnel ventilation system. Furnish spare booster fan assemblies complete with all accessories to make it readily interchangeable with any one of the booster fan assemblies removed and taken out of service for maintenance in the future.~~

V05.3.12.2 Package spare fan assemblies separately and deliver and unload at a site designated by the Authority at a later date. Package all spare items suitable for long-term indoor storage, and identify each package clearly with the Contract number, description and quantity of the contents.

DATA SHEETS FOR JET FANS		
Type-		Tubular Tube Axial Flow with short casing
Reference Code / Standard		BS EN ISO 9001
Flow Direction		as per BOQ
Thrust		As specified in BOQ
Noise Criteria		Refer to Notes
High Temperature Operation		2 Hours @ 250 °C
FAN	Blade	Aerofoil Construction, Dynamically Balanced , Adjustable
	Material	Cast Aluminum
	Bearings	Fan mounted on motor Shaft
	Hub	Cast Aluminum
	Casing	Rolled Steel Sheet, Heavy Gauge
	Shaft	Impellor mounted on motor shaft
	Mounting	Shaft Key And Positive Locking Device
Drive Arrangement		Direct Drive
Motor	Type	TEFC Induction Motor,EFF-1, Continuous Duty
	Design	As Per or Relevant ISO Standard/ Relevant IEC
	Connection	Three Phase, 415 V, 50 Hz, AC Power Supply
Paint		Epoxy Paint after Surface Treatment For Corrosion/ Hot Dipped galvanized surface
NoiseAttenuator	Type	Square, Rectangular Flange Type
	High Temperature Operation	Two Hour's @ 250 °C
	Construction	To Comply with DW 144 Class B Code

	Casing	1.6 mm thick Pre GSS
	Casing Material	GSS G 275
	Acoustic Fill	Fiber Glass With DETR Class ‘O’ Flame Spread OR As per class A of ASTM E 84
	Internal	0.8 mm thick perforated SS-316
	Splitters	0.8 mm thick perforated SS-316
	Mounting Arrangement	Suitable Bracket For Ceiling Suspension
	Lifting Arrangement	Lifting Eye At Suitable Location And Number
	Casings To Be Formed With Either stand Up Or Lock Formed Seams With Mastic Sealant	

Notes

1) Thrust to be verified by Contractor based on final equipment offered.

2) Length of noise attenuator to be determined by the Contractor based on the equipment offered and the following:

Tunnel noise criteria is 80 dB(A) during operation of tunnel ventilation equipment.

Platform noise criteria is 75 dB(A) during operation of tunnel ventilation equipment.

Tunnel Ventilation Fan Room Noise criteria is 85 dB(A) during operation of tunnel ventilation equipment.

External noise criteria is 55 dB(A)at nearest property line during operation of tunnel ventilation equipment.

3) The fans shall be as per DMRC specifications enclosed. All accessories mentioned in specifications shall be included in the tender.

4) Vender shall furnish following data with his offer

i) Fan performance curve for each direction of rotation

ii) Dimensional Sheets

iii) Fan Data Sheets

iv) Fan sound power levels for complete octave band for forward & reverse direction.

Section V 06 Compressed Air System

TABLE OF CONTENTS

V06.1 Dampers

V06.1.1 Dampers shall be operated by electro-penumatic actuatores mounted outside of the damper frame wherever possible. If contrcator is not able to commission the compressed air system before starting operational test of dampers due to any reason, he should arrange portale compressors in sufficent numbers so as the tesing can be completed on time.

V06.2 Air Compressors

V06.2.1 The compressors shall be complete with all integral controls and saftety devices and shall be rated at the performance stated in the Equipment Schedule with a tolerance of ± 3% (I SO1217 or equivalent).

V06.2.2 The compressors shall be suitable for 24-hours operation per day with control from pressure switches. The compressors shall be complete with control panel featuring manual lead/lag selector switch or it can be achieved by manual pressure setting of compressor, motors, and starters.

V06.2.3 The motor control panel shall be incorporated with automatic daily lead-lag sequence of the air compressors for optimum efficiency oepration. The compressors shall be in full-capacity standby mode, and arranged so that automatic changeover takes place if the slelected air compressor fails to start within a pre-determined length of time. On initial start-up and intermediate increase of compressed air demand consumption, both compressors shll run until the desired compressed air pressure is reached. The oepration of the compressor shall be cut out by high pressure cut-out or overload status.

V06.2.4 The following indicators/selectors switches shall be included in the compressor motor control panel :-

1. Running hour meter
2. Manual/Auto selection switch
3. Pressure indicator
4. Temperature indicator
5. Duty/standby selection switch with automatic/ Manual sequence control (manual pressure setting of compressor periodically)

V06.2.5 The compressors shall be pulsation-free and the noise level generated from the machines shall not exceed 75 dB(A) under normal operating condition; measured under field condition at a distance of 1m with maximum deviation of ± 3 dB(A).

V06.2.6 External air intake pre-filters shall be fitted and details or replacement units, their cost and useful life shall be provided with the Tender.

V06.2.7 Inlet air to the compressor shall be taken from ambient air.

V06.2.8 A warning sign, 4mm thick plastic plate, with the following wording in English of character height not less than 16mm to be added in the vicinity of the air compressors;

"This compressor is automatically controlled and may start without warning".

The Contractor shall submit the detailed format of the above warning sign for approval.

V06.3 Air Tanks/Receiver

V06.3.1 Each air receiver shall be of horizontal welded steel type complete with inlet and outlet connection, pressure relief (safety) valve, inspecting opening, tappings for drain valve, and pressure gauge. The receiver shall confirm to ASME Sec. II/ IS 2825/ BS5169/ BS5750 and have a capacity as specified in the Equipment Schedule.

V06.3.2 Each receiver shall bear a 4mm thick plastic plate label on which the following indication wording in English of characters height not less than 6mm shall be engraved :-

1. Manufacturer : ______________________
2. Model Number : ______________________
3. Normal Design Pressure : ______________________bar
4. Maximum Design Pressure : ______________________bar
5. Maximum Design Temperature: ______________________^{0}C
6. Hydraulic Test pressure : ______________________bar
7. Date of Test : ______________________

V06.3.3 The Contractor shall submit the detailed format of the above label for approval.

V06.4 Refrigerated Type Air Dryer

V06.4.1 The air dryers shall be capable of producing dry air at a dew point of -4^{0}C of free air at 7.5 bars gauge based on continuous operation. The refrigeration circuits shall be fully contained to provide a reliable, independent package.

V06.4.2 The air dryers shall have built-in automatic drain valves so that the unit operates with continuous drain to a separator , with periodic blow down to drain condensate.

V06.4.3 The air dryer shall employ the dew point control panel to Indicate the continuous reading of dew point value.

V06.5 Air Pre-filters (Boro silicate glass fiber disposable type)

V06.5.1 Coalescing pre-filter shall be assembled on the air intake side of the wet gas inlet of the refrigerant air dryer. The steel/ die cast aluminium housing of the pre-filter shall comply BS 5500, and the filter medium shall be composed of layers of fine glass fibers integrally epoxy bonded as a strong sheet to remove particle down to 1 micron

VO6.5.2 The rated differential pressure an operating temperature of the pre-filter shall be consistent with the intended rating of the compressed air plant.

V06.5.3 The pre-filter shall consist of drain valve and sump to facilitate periodical draining of the housing either automatically or manually.

V06.6 Air After-filters

V06.6.1 After-filter shall be assembled on downstream side of the air dryer to filter any particulate matter (e.g. dust, dirt) with diameters larger than 0.01 micron, from the treated compressed air supply stream.

V06.6.2 The rated differential pressure an operating temperature of the after-filter shall be consistent with the intended rating of the compressed air plant.

V0.6.6.3 not used

V06.7 Compressed air Drain Assemblies

V06.7.1 Drain trap assemblies shall be provided at the base of each vertical branch main moisture separators air receivers, and at intervals not exceeding 30m of horizontal pipe run.

V06.7.2 The assembly shall consist of an isolating valve, strainers, compressed air trap and liquid discharge pipe. The discharge pipe shall be extended to the nearest gully or drain.

V06.7.3 A pressure balance pipe shall be fitted between the branch main, separator inlet or air receiver where shown to be necessary.

V06.8 Pressure Reducing Sets For Compressed Air

V06.8.1 Sets shall comprise a moisture separator, with trapped drain, stop valve, strainer with blow down provision, inlet pressure gauge, pressure reducing valve, stop valve, and safety relief valve with drain line to low level. An outlet pressure gauge shall be provided one meter downstream of the downstream connection of the by-pass pipe.

V06.8.2 The complete assembly shall have a full bore by-pass pipe with valve.

V06.8.3 The pressure reducing valve shall be supplied with filtered compressed air for operation, through a regulator.

V06.8.4 A valve pressure control pipe shall be installed between the pressure reducing valve an the low pressure side close to the pressure gauge.

DATA SHEET FOR AIR COMPRESSORS	
Service	Damper Operation
Gas Handled	Atmospheric Air
Volume : M^3/minute	0.79
Inlet Conditions	
Pressure	Atmospheric
Temperature (°C)	Max 46 °C
Relative Humidity (%)	Max 95%
Discharge Conditions	
Pressure (Bar G)	13
Temperature (°C)	Not more than 45°C
Rated Speed (rpm)	Not more than 1450 rpm
Volumetric Efficiency (%)	95%

Note

1) The compressors shall be mounted over horizontal Air Tank. Compressed air shall be stored in compressed Air tank prior to entering the refrigerated dryer.
2) All components of compressor shall be installed in a sound proof enclosure to reduce the noise.
3) Pre-filter shall be provided over the enclosure for maintaining cleanliness.
4) Complete unit shall be suitable for floor mounting.

5) Other accessories like pre-filters, post filters, moisture separators etc shall be provided.

6) The complete package shall be as per specifications enclosed with the tender.

7) The motor control panel shall be incorporated with automatic daily lead lag sequence of the air compressors for optimum efficiency operation. The compressors shall be in full-capacity standby mode, and arranged so that automatic changeover takes place if the selected air compressor fails to start within a pre-determined length of time. On initial start-up and intermediate increase of compressed air demand, both compressors shall operate till the correct compressed air pressure is reached. The operation of the compressor shall be controlled through high pressure cut out or over load.

The following indicators/selection switches shall be included in the compressor motor control panel.

1. Running hour meter
2. Manual/auto selection switch
3. Pressure indicator as per specifications
4. Temperature indicator as per specifications.
5. Duty/stand by selection switch with automatic sequence control/ Manual sequence control

The compressors shall be pulsation free and the noise level generated from the machine shall not correct 75 dBA under normal operating condition measured under field condition at a distance of 1 Meter.

External air intake pre-filters shall be fitted and details of replacement units. Their cost and useful life shall be provided with the tender.

Inlet air to the compressor shall be taken from a dry cool location.

A warning sign 4mm thick plastic plate, with the following wording in English of character height not less than 16mm to be added in the vicinity of the air compressors.

This compressor is automatically controlled and may start without warning

The Contractor shall submit the detailed format of the above warning sign for approval.

BMS/ 1.00 SPECIFICATIONS FOR ECS & TVS BUILDING MANAGEMENT SYSTEM

TABLE OF CONTENTS

BMS FOR ECS & TUNNEL VENTILATION SYSTEM

BMS/ 2.00 GENERAL, CODES AND STANDARDS

BMS/2.01.1. Purpose and Scope

This Specification describes the minimum standards of the Building Management System (BMS) for ECS & TVS system for JMRC.

The Works to be executed under the Contract include the design, development, manufacture, verification, delivery, installation, testing, commissioning (including integrated testing and commissioning) and technical support for a complete BMS to fully integrate the control, monitoring, and supervision of Environmental Control Systems, Low Voltage Power & Distribution, Fire Alarm System, Hydraulic System (Seepage, Sewage, Bore Well Pumps etc.), and other nominated Building Services Systems including all PLC Equipment, CPU's, Modules, Sub Modules, Power Supplies, Local Control Panels, PC Work Stations, Printers, Local Area Network (LAN), Ethernet Hubs and Switches, Interface with electrical containment and wiring systems, and other components as required whether or not specified necessary to deliver the requirements of this Specification. The BMS shall also interface with the requirements of the Non Power SCADA (NP SCADA), for control, monitoring, and supervision as required at the Operational Control Centre (OCC).

The Works to be executed under the Contract also include the detailed design, development, manufacture, verification, delivery to site, installation, testing, commissioning (including integrated testing and commissioning) and technical support for a complete Integrated Supervisory Control System (ISCS) to fully integrate the control, monitoring, and supervision of Tunnel Ventilation System from OCC as well as from station level. The Equipment, CPU's, Modules, Sub Modules, Power Supplies, Local Control Panels, Servers, Work Stations, modems, Gateways, RTU/ Redundant Server, Printers, Local Area Network (LAN), Ethernet Hubs and Switches, Ventilation Control Panel (VCP), Cable containment and wiring systems, and other components as required whether or not specified necessary to deliver the requirements of this Specification to fully integrate the control, monitoring, and supervision of Tunnel Ventilation System from OCC as well as from station level and for control, monitoring, and supervision as required at the Operational Control Centre (OCC) for the ECS and other E&M systems . The TVS contractor shall interface with the requirements of control, monitoring, and supervision as required at the Operational Control Centre (OCC) for the E&M systems also . Communication channel between station to OCC and stations will be provided by others.

The BMS & ISCS is to be designed manufactured, supplied, installed, tested and commissioned by the Contractor and shall meet all performance and functional requirements as defined in the Specification.

This specification contains a general description of the system concepts and major components, and sections covering definitions, requirements for interfaces with other contracts, general mechanical and electrical installation design/performance requirements, and testing requirements.

The emphasis is to explain the requirements of work, interfaces with other contractors for achieving an efficient & safe working system commensurate to the best international standards and practices. Every effort has been made to cite the design requirements very clearly, however in this Design & Construct contract, the contractor shall follow acceptable standards & design procedures akin to the best available in world Metros where this is not explicitly mentioned.

In this document the term “provide” shall mean “the detailed design covering specifications, calculations, drawings for installations & maintenance, manufacture and factory testing or procurement, delivery, off-loading, installation, testing, commissioning, handover to JMRC, JMRC staff training including supply of O & M manuals & as-built drawings, interface and co-ordination with other contractors or arising out of concurrent works and warranties”.

Submittals shall be in the form of reports, drawings, calculation sheets & schedules both in hard copy and on computer diskette. The contractor shall furnish backup materials such as codes / Standards / software programs free of cost for the Employer’s Representative’s use in understanding/evaluation of the submittals. The contractor will furnish a list and format of submittals for each area of work to the Employer’s Representative for consent covering the requirements given herein.

The design and supply of elements shall be to international specifications and standards, which must be stated at the time of tendering. Approved local standards shall also be complied wherever necessary. The designs shall be fully integrated with compatible components including where these interface with other contractors’ works.

Unless approved otherwise, all equipment items shall be uniform throughout the Contract in order to minimize maintenance spares and the number of manufacturer interfaces.

Codes and Standards

BMS/2.01.2. Local Codes, Regulations and Standards

Notwithstanding any specific reference elsewhere in this document, the Contractor shall comply in every respect to the requirements of NFPA 130 - Fixed Guide way Transit Systems, Latest Edition particularly in respect to Life Safety Systems. Any items of non-compliance shall be clearly identified to JMRC at the time of tender, and any relaxation of any such non-compliance item shall require the prior approval of JMRC in writing.

Where any ambiguity occurs between the requirements of NFPA 130 - Fixed Guide way Transit Systems, Latest Edition and these specifications, the more onerous clauses shall apply unless relaxation is approved in advance by JMRC in writing.

Unless otherwise stated, and only in the absence of suitable international standards, the Building Management System (BMS), design shall be governed by all applicable local codes, regulations and standards.

BMS/2.01.3. Additional Codes, Standards, Specifications and Manuals (PLC)

In addition to local requirements, BMS designs shall also comply with the following codes of practice, standards, specifications and manuals.

BMS/2.01.4. Local Codes

Local codes, regulations and standards shall take precedence where these standards or requirements are more onerous than other international standards.

- Indian Electricity Rules
- Indian Electricity Act
- National Building Code
- Chief Inspector (Electrical) (for Lifts), Govt. of NCT OF Jaipur.
- Central Pollution Control Board
- Jaipur Fire Services
- Jaipur Public Works Department
- Central Public Works Department
- BSES Rajdhani Power Limited
- Chief Electrical Inspector for Jaipur MRTS
- Jaipur Administration
- Municipal Corporation of Jaipur
- Jaipur Municipal Corporation
- National Safety Council

BMS/2.01.5. International Codes

- NFPA 130: 2003 - Fixed Guideway Transit Systems: any non-compliance shall be approved in writing by the JMRC.
- British Standards or other internationally recognized standards as approved by the Employer's Representative.
- The Guides of the Chartered Institution of Building Services Engineers.

BMS/2.01.6. International Standards

Reference/Abbreviation		Description
NEMA	**:**	**National Electrical Manufacturer's Association**
ICS-1	:	General Standards for Industrial Control and Systems.
ICS-1.1	:	Safety Guidelines for the Application, Installation and Maintenance of Solid-State Control.
ICS-2	:	Industrial Control Devices, Controllers and Assemblies.
ICS-3	:	Industrial Systems.
MG-1	:	Motors and Generators
MG1-12.54	:	Efficiency
UL	:	**Underwriter's Laboratories, Inc.**

508	:	Industrial Control Equipment

The standards to be followed during the design, construction, and installation of the BMS shall be generally as listed, except where specific requirements are given in the Specification, which shall take precedence. The Contractor may propose alternative or additional standards for review by the Employer's Representative at least 60 days before application.

All codes and standards shall be submitted in English language. The design of any one system shall be to a single code or specification. The parallel use of different codes for particular items or components shall not be allowed.

BMS/2.01.7. Definitions and Abbreviations

Abbreviations used in this specification include:

Abbreviation		**Meaning**
A	:	Amps
AC	:	Air-Conditioning
ac / AC	:	Alternating current
AHU	:	Air Handling Unit
BMS	:	Building Management System
BS	:	British Standard
CIBSE	:	Chartered Institute of Building Services Engineers
DB	:	Dry Bulb
dB	:	Decibel (sound pressure level)
dc / DC	:	Direct current
JFB	:	Jaipur Fire Brigade
JMRC	:	Jaipur Metro Rail Corporation
ECS	:	Environmental Control System
EN	:	Euronorm Standard
ESPS	:	Escalator Sprinkler Protection System
EV	:	Ventilation Exhaust Shaft
FAP	:	Fire Alarm Panel
FCP	:	Fireman's Control Panel
FOC	:	Fire Officers' Committee
HV	:	High voltage
IES	:	Illumination Engineering Society, UK

Abbreviation		Meaning
IS/BIS	:	Bureau of Indian Standards
ISO	:	International Standards Organisation
kVA	:	Kilo volt-amps
kW	:	Kilowatts
LDC	:	Local Digital Controller
LPC	:	Loss Prevention Council
LV	:	Low voltage
MCC	:	Motor Control Centre
MJC	:	Multiple Jet Control
Mm	:	Millimetres
MV	:	Medium voltage
NC	:	Noise criterion
NFPA	:	National Fire Protection Association, USA
OCC	:	Operations Control Centre
OCS	:	Overhead Catenary System
OTE	:	Over Track Exhaust
PLC	:	Programmable Logic Controller
RI/O	:	Remote Input & Output
rpm	:	revolutions per minute
SCADA	:	Supervisory Control and Data Acquisition
SCR	:	Station Control Room
SV	:	Supply Air Shaft
TBD	:	To be decided
TBF	:	Tunnel Booster Fan
TEF	:	Trackway Exhaust Fan
TES	:	Trackway Exhaust System
TVF	:	Tunnel Ventilation Fan
TVS	:	Tunnel Ventilation System
UPE	:	Under Platform Exhaust
V	:	Volts
VAC	:	Ventilation and, Air-Conditioning

Abbreviation		Meaning
WB	:	Wet Bulb

BMS/2.01.8. Voltage Definitions

(av.) “voltage” means the difference of electric potential measured in volts between any two conductors or between any part of either conductor and earth as measured and a suitable voltmeter and is said to be:

"Low " where the voltage does not exceed 250 volts under normal conditions subject, however, to the percentage variation allowed by the rules;

“Medium” where the voltage does not exceed 650 volts under normal conditions subject, however, to the percentage variation allowed by the rules;

“High” where the voltage does not exceed 33,000 volts under normal conditions subject, however, to the percentage variation allowed by the rules;

“Extra High” where the voltage exceeds 33,000 volts under normal conditions subject, however, to the percentage variation allowed by the rules;

BMS/2.01.9. Electrical Design Works Codes and Regulations

Equipment, materials and systems shall be designed, manufactured, and tested in accordance with the latest issue of codes and standards.

Electrical design shall be based on BS 7671: 1992 "Requirements for Electrical Installations" or other internationally recognised equivalent standard that are approved by the Authority examples of which are given below.

Unless otherwise stated, the electrical system design shall be governed by all applicable local codes, regulations and standards issued by the local agencies.

Reference/Abbreviation		Authority
ANSI	:	American National Standards Institute
ASME	:	American Society of Mechanical Engineers
ASTM	:	American Society for Testing and Materials
BIS	:	Bureau of Indian Standards
DIN	:	Deutsche Industrie Normen
IEC	:	International Electrotechnical Commission
IEEMA	:	Indian Electrical and Electronics Manufacturers Association
JIS	:	Japanese Industrial Standards
NEC	:	National Electrical Code (NFPA 70)
NEC		National Electrical Code (Indian)
NEMA		National Electrical Manufacturers Association

Reference/Abbreviation	Authority
NFPA	National Fire Protection Association
VDE	Verband Deutsche Elektrotechniker
	Local Codes, Regulations and Standards

Any additional requirements imposed by local agencies not listed above shall be incorporated into the designs. The contractor shall prepare a check list based on relevant standards for ensuring conformity in design, manufacture, supply / storage, packing, erection / commissioning and operation as applicable. The contractor shall obtain approvals from relevant authorities at appropriate stages of work.

BMS/2.01.10. Additional Codes, Standards, Specifications and Manuals (Electrical)

In addition to local requirements, electrical system designs shall comply with the codes of practice and standards specified in the Outline Design Criteria. Local codes, regulations and standards shall take precedence where these standards or requirements are more onerous than other national standards.

All codes and standards shall be submitted in the English language.

The design of any one system shall be to a single code or specification. The parallel use of different codes for one particular item or component will not be allowed.

BMS/2.01.11. Control Room Definitions

Definitions used in these criteria are as follows :

Ancillary Rooms - the non-public areas or spaces of the stations which contain operating, maintenance, Local Control Panels (LCP), or other associated support equipment and functions.

Operation Control Centre -the operations centre that controls and co-ordinates the system-wide movement of passengers and trains and the point from which communication is maintained with supervisory and operating personnel.

Station Control Room – the local control room at the station for operational control of the station and to monitor station activities and functions relating to the movement of passengers and trains along with auxiliary and support systems including the Fire Alarm Panel (FAP), and Ventilation Control Panel (VCP), for manual override of the TVS Modes.

BMS/2.01.12. Work Included in the Services

The Services to be performed by the Contractor **shall include, but not be limited** to, the following:

- Detail Design, manufacture, verification, delivery, installation, testing, commissioning and technical support for a complete, Integrated Supervisory Control System (ISCS) to fully integrate the Tunnel Ventilation System and to implement the control, monitoring, and supervision as required at the Operational

Control Centre (OCC) and station level to implement the control, monitoring, and supervision as required at the Operational Control Centre (OCC) for ECS and E&M works.

- Presentations, reviews and audit support as specified in the Specification;
- interface management as specified in the Specification;
- system operations and maintenance support services;
- training for the Employer's Engineers and Training Instructors, operations staff, maintenance staff and Engineering staff;
- decommissioning, removal and/or disposal of Temporary Works;
- prototyping and prototype testing;
- warranty period after commissioning.
- All software development & supports.

The list is not intended to be complete and the contractor shall supplement it adequately for obtaining a satisfactory working Metro system akin to the best standards available worldwide.

BMS/2.01.13. Work Excluded

A LAN in the station areas will provide a data link for all station equipment. This LAN will communicate with the OCC via the FOTS. The Designated contractor will only provide the main communication network and the Local Area Network (LAN) located in the OCC. The LAN shall be used by the Tunnel Ventilation System as a data communication link along with other systems in the OCC. The Station LANs will be provided by the TVS Contractor and will provide a data link between the Tunnel Ventilation System and other systems located within or near the station

BMS/2.01.14. Included in the Scope of Supply

The Contractor **shall supply all equipment and facilities necessary to meet the requirements of this technical specification**, including, **but not limited to**:

- All necessary equipments at OCC whether specified or not specified like work station, RTU/Redundant Server, Modems, Gateways , switches and other associated accessories including cables their containment arrangement necessary to provide for control, monitoring, and supervision of Tunnel Ventilation System from OCC as well as from station level and **monitoring of** ECS ,PS and BS system from OCC.
- Work Stations in all the stations, PLCs, VCP, LCPs, Ethernet switches, Printers, Pressure Differential–**transducer**, Temperature and Sensors, transducers and other equipment as defined in the BOQ and required for efficient working of ISCS system.
- Control equipment, including accessories / components,
- All cable trays, cables and cabling necessary for the ISCS Works;
- Enclosures and supporting brackets for housing and fixing equipment;

- Earthing of all equipments as defined in the specifications;
- All equipment associated with any interfaces required to ensure operation within the performance requirements;
- All equipment necessary to allow the introduction of future services without disruption to Phase I services;
- All special test equipment and tools, including data configuration tools;
- Maintenance tools;
- All equipment necessary to carry out factory and on site testing and commissioning;
- All software, appropriately safety validated, verified and certified, to meet the requirements of the Specification;
- All software and hardware required for data logging;
- The BMS contractor will be responsible for sealing with fire rated material of all openings left due to BMS works.

BMS/2.01.15. Services Provided by System-wide Contractors

BMS/2.01.16. Operations Control Centre (OCC)

The System-wide contractor shall provide the main communication network upto the OCC from stations . The same shall be used by the TVS SCADA system as a data communication link along with other systems in the OCC.

BMS/2.01.17. Station Area Network

A LAN in the station areas will provide a data link for all station equipment. This LAN will communicate with the OCC via the FOTS. The Station LANs for TVS work will be provided under this contract and will provide a data link between the BMS and other systems located within or near the station.

BMS/2.01.18. Main Cable Routes

Main cable routes, including cable trays, troughs, hangers, trenches, and ducts, shall be coordinated with the VAC and E & M Contractor.

BMS/2.01.19. Safety and Escape

The design of the BMS shall comply in all respects to the provisions for safety and escape in accordance with the requirements of NFPA 130 Standard for Fixed Guideway Systems latest edition.

BMS/2.01.20. Standardisation

The Contractor shall, in establishing his design, follow the principles provided below in the design and specification of all plant, equipment and components:

- Similar plant and equipment shall be replaceable/interchangeable, modular in design, adaptable and extendable.
- The technical specifications and design standards shall be uniform. Uniform standards for clear spaces, working clearances, protection of equipment and physical dimensions of equipment and interfacing with other systems.

- Type testing, routine testing and endurance test shall be required under similar conditions. Evaluation shall be conducted at all stages and performance compared with acceptance criteria. Testing values shall be commensurate with reference standards.
- Test standards and standardised equipment shall be selected or built or framed carefully, bench marked, designated and explicitly marked.
- A standard procedure shall be followed for identification of each category of equipment explicitly (suffixing or prefixing while marking and numbering for each category of equipment).
- Similar principles of establishing footprints of plant and equipment shall be followed.
- The operating system shall be uniform for all systems/sub systems.
- Standards for maintenance planning shall be uniformly categorised.
- Uniform standards shall be designated for procurement, replacement stocking and availability.
- Equipment and accessories shall be provided with uniform standard spare capacity, protection.
- Piping, cabling etc. shall be suitably colour coded for identification and categorisation for each kind of use/type.

BMS/2.01.21. Qualifications of Equipment Manufacturer and Providers

The BMS equipment shall be furnished by manufacturers who have manufactured similar control system equipment for a period of at least five years.

BMS shall be installed, tested, commissioned and adjusted under the direct supervision of the manufacturer or his authorised agent.

Installation of BMS controls shall be by experienced personnel under the direct supervision of trained and qualified Employer's Representatives.

All items necessary to make the BMS installation complete in every respect, safe and ready for regular operation and use, and for easy maintenance shall be furnished by the Contractor.

In design and purchase of equipment, the interchangeability of items, subassemblies, modules, parts, motors, starters, relays, and transducers shall be considered.

BMS/2.01.22. Certification of Personnel & Work

All the workmen & supervisory staff shall be qualified and certified licence holders or have competence certificate from national/internationally recognised agency empowered to issue certificate for carrying out similar work.

The methodology shall be designed to obtain certification of the work through check list, and standards .The installations shall be checked by a quality assurance team having the representatives from Employer's and contractor's side.

The contractor shall be responsible for including all safety aspects in his design, the proper selection of equipment, protection schemes etc. correct installation, testing & commissioning.

The contractor shall obtain prior approval for energisation / commissioning from the competent authority in accordance with statutory regulations in force. The contractor shall list out such statutory requirements and shall issue a certificate of compliance in above respect before energisation / commissioning.

BMS/2.01.23. Quality Control of Equipment, Components and Material

The contractor shall furnish the following information for each item of equipment as applicable:

- Manufacturer.
- Type and model No. of equipment.
- Nominal capacity in VAR/kW.
- Overloading capacity.
- Short time rating, continuous rating.
- Power supplies i.e. Voltage & Frequency at which the equipment operates.
- Type of Frame and foundation required for the equipment.
- Space requirements
- Controls & Protection
- Indications/alarm/annunciation
- Standards
- Insulation class
- EMC Conformance and certification.
- Any other technical information related to the equipment.

The contractor shall provide a list of tools and test equipment for the repair of any special apparatus and proposals for conducting system acceptance testing and to support the extended period of trial running.

BMS/2.01.24. Computer Simulation

Where applicable, the designs shall be substantiated through computerised simulation of calculations, Data verification and validation programs using standard simulation programs, internationally accredited or indigenously developed, supported with quality verification and acceptability and shall provide input data, results and program description.

The contractor shall furnish free of charge software packages whose use is envisaged. All the software shall have an in-built data validation program so as to identify/rectify parameters/variables selection or typographical error with future ability to upgrade.

BMS/2.01.25. Corrosion Protection

The contractor shall design to provide and state the corrosion protection systems used and the design lives of the systems. The contractor shall show that the works have an adequate coordinated protection system, against all types of corrosions.

The corrosion protection systems used and the “design” lives of the systems be stated. A test is required to be carried for monitoring the predicted results on corrosion. Suitable test points for the installed protection system shall be provided.

BMS/2.01.26. Training of Operating and Maintenance Personnel

The contractor shall:

Prior to final inspection or acceptance, shall provide all necessary manuals, training aids, and other related materials to adequately train and instruct designated operating and maintenance personnel in the operation, adjustment, and maintenance of all equipment and systems.

Explain to O&M personnel, in full and to their complete understanding, all procedures necessary to operate and maintain all equipment and systems on a continuing basis.

Prepare and review the contents of the O&M Manuals with O&M personnel in full detail to explain all aspects of the Manual and the operation and maintenance of all equipment and systems.

BMS/2.01.27. Submission of Drawings & Details

The contractor shall provide sections through the station service routes as may be required by the Employers representative to show the adequacy of false ceilings etc. to accommodate services and layout drawings showing location of all major components wherever necessary.

The contractor shall state the number and scales of all the drawings like Combined Services Drawings (CSD) and of Structural/Electrical Mechanical (SEM) Drawings it intends to produce in support of the works under this contract. The detailed/schematic drawings to be furnished by the Contractor may include but not be limited to:

- Combined Services Drawings (CSD)
- Structure Opening Drawings
- Structural/Electrical Mechanical (SEM) Drawings
- Structural drawings
- Fabrication drawings
- Schematic drawings
- Interlock drawings

- Erection drawings
- Wiring drawings
- As erected/finished drawings

A complete schedule of drawings to be produced by the contractor shall be submitted to the Employers representative within one month (30 days), of contract award.

BMS/2.01.28. Acceptance Criterion

The contractor shall furnish the acceptance criterion for the equipment/services supplied/provided by the manufacturers/suppliers during execution of the work and furnish a checklist for each of the equipment /service provision/verification/testing and acceptance in line with the specified requirements for achieving best quality of job.

BMS/2.01.29. Particular Specification

The contractor shall prepare technical material and workmanship specification for manufacture or supply and installation of all PLC Control System for the Tunnel Ventilation System (TVS) works in the style of the Construction Standards Institute (CSI) of America's three part format:

Part 1 - General

Part 2 – Materials and Products

Part 3 – Execution

Each specification shall be complete in itself and shall contain as relevant such diverse requirements for :

Part –1 - Description, standards, testing, tolerances and submittals

Service requirements and technical requirements, delivery, storage and handling, Interfacing with other system-wide contractors.

Part – 2 - Materials

Manufacture/supply, protection scheme, monitoring and testing.

Part –3 - Installation and commissioning.

Inspection, testing and, corrective work.

The specifications shall include but not be limited to such subjects as:

- General & Design Requirements.
- Specifications for Equipment, components and Materials.
- Specifications for control panels.
- Specifications for medium voltage power cables and control cables.
- Specifications for earthing systems.
- Specifications for control and monitoring of the BMS system.

- Any other specification required for completing the above works.

BMS/2.01.30. Design Considerations

The complete installation shall be in strict accordance with the national and local electrical codes. All devices designed for or used in line voltage applications shall be U.L./CE.

A) All system components are to be designed and built to be fault tolerant:

- Satisfactory operation without damage at 110% and 85% of rated voltage and at +3 hertz & - 1.5 Hz variation in line frequency.
- Static, transient, and short circuit protection on all inputs and outputs.
- Communication lines protected against in-correct wiring, static transients and induced magnetic interference.
- Bus connected devices to be a.c. coupled or equivalent, so that any single device failure will not disrupt or halt bus communication.

B) All equipment, cables and wiring shall be designed, manufactured and installed so as to secure a service life as shown below:

- Control Panels 10 Years
- Cables 30 Years
- Tray, trunking and supports 30 Years
- Sub-assemblies and components 10 Years
- All other equipment 10 Years minimum

C) Switchboards, equipment, and other control components shall be rated for operation in ambient temperatures of 40°C and humidity up to 75% and shall have degree of protection IP-65 /54.

In the design of switchboards and local control panels an allowance of 20-25% spare capacity shall be provided for possible future expansion and all panels shall be user friendly, modular and aesthetic design, termite and vermin proof.

BMS/2.01.31. Tender Submittal Procedure

To allow evaluation of vendors and the systems being offered, a detailed technical proposal shall be provided and formatted strictly in accordance to this outline. Vendor's standard literature not complying to this format and content requirement will not be considered or evaluated. Proposal requirements are as follows:

- Proposed system complete with location and block diagram including central computer type and memory, peripherals, communication interfaces, all LAN cards, all active hubs and repeaters, network layout, distributed peer bus connected control/monitor panels with location, listing of equipment directly connected to a peer bus controller, and secondary network drivers and connected systems.
- Provide copies of required UL listing cards.
- Technical Compliance - Provide TYPED responses to each point of Technical Compliance

- Deviation Schedule - For each item of conditional or non-compliance, provide the vendor's substitute response to the feature excepted or deviant to the specifications.
- System write-out / Description of the proposed BMS Control System.

The following functions/items shall be included in the proposal for system evaluation.

- Computer based central:
- Day-to-day interactive operator interface description with sample English/Graphic displays, penetration scheme for display/command and logical configuring, and examples of alarms and data in various modes (disabled, fixed, not responding, etc.).
- Short cut penetration schemes for direct graphic, point, and command access.
- Colour-graphic system description with sample system displays, colour-graphic penetration and command schemes, graphic creation means, library of symbols, and curve plot.
- Interactive data editing scheme for modification of system data base and parameters including operators, peripheral assignments, system configuration, text, time schedules, point monitoring limits, event initiated control, and control application program parameters.
- Data Segregation control and security scheme.
- Report descriptions including selection scheme and sample reports.
- Programming facility including language and canned packages of sub-routines and intrinsic functions.
- Sample sequence of operation and flowchart display.
- Sample text alarm message.
- Sample custom report.
- Sample of system and point descriptor text.
- Technical description of all hardware components.
- Distributed control panel point architecture, memory, battery.
- Functional description
- Control and survival capabilities
- Life safety interfacing
- Communications network architecture, points, panels.
- Bus limitation, distances between active links and hubs, etc.
- Point sharing/update scheme.
- Description of the System

The BMS shall, as a minimum, incorporate the capability of Energy Management, Equipments Monitoring and Control, which consists of the following elements:

Microprocessor-based PLC Control Processors shall interface directly with sensors, actuators and environmental control systems (i.e. HVAC units, chillers, pumps, etc.). Functionality to be implemented at the PLC level include:

- Individual input/output point scanning, processing and control.
- Digital Controls.
- Energy Management.
- Alarm Detection.
- Time, event and holiday scheduling.
- Temporary Scheduler.
- Bus communications interface and control.
- Customising of application software using Object Oriented Programming Language

BMS/2.01.32. Additional Certification Requirements

The Contractor shall submit the following PLC manufacturer certificates with the tender.

- Estimated mean time between failure (MTBF)
- Estimated mean time between service failure (MTBSF)
- Mean time to repair (MTTR)
- Mean time to maintenance (MTBM)

BMS/ 3.00 DESIGN AND PERFORMANCE REQUIREMENTS

BMS/3.01.1. General

Equipment or systems comprising several components shall be controlled through the BMS with suitable control regimes to achieve desired operation normally automatically but with provision for manual intervention. The automatic operation shall conform to the operational, functional and overall system needs as specified in the following descriptions.

The equipment shall enable monitoring through a station control Operator Workstation, operator's desk for commands and warning-cum-alarm units. This panel shall be located at the station control room

The transmission of information between the equipment and the station control panel is entirely the responsibility of the equipment supplier through suitable cableways. The equipment contractor shall prepare in clear and logical form documents describing the functions transmitted and the operations carried out at the stations control room. The control and transmission scheme shall be submitted for the consent of the Employer or his representatives.

The equipment shall also have arrangements to log and record various parameters on a regular basis and store the critical results for at least six months. The contractor shall also provide portable equipment such as Notebook, PCs for extracting information from the logic at the digital control equipment and then store for any future use for maintenance or planning.

The information transmitted between the equipment and the OCC shall be carried by TVS SCADA equipment supplied by under the scope of this contract. The Contractor shall draw a table indicating the various number, type and physical layout of the terminals used for transmitting the statuses or the measurements to the OCC and provide this information in clear logical form in accordance with the project programme.

The equipment shall be capable of providing the outputs and using the inputs at the interface terminals over voltage free contacts. The equipment on the side of the interface receiving the information shall provide the power supply and the sending side shall provide the voltage free contacts.

The physical characteristics and data transmission protocol proposed shall conform to an internationally recognised publicly available standard.

BMS/3.01.2. Design Coordination Requirements

BMS/3.01.3. General

The following design requirements shall be adopted by the Contractor and are in addition to those that may otherwise be specified in the Employer's Requirements.

The Contractor shall submit a list of all design review documents for the review of the Employer's Representative.

BMS/3.01.4. Design Process

The Contractor shall adopt a structured design process, including, but not limited to:

- Conceptual, preliminary and final (definitive) design and reviews with the Employer's Representative for the BMS.
- Conceptual, preliminary, and final (definitive) design and reviews with the Employer's Representative, for the software design, including but not limited to: the software requirements specification, software architecture, logic flow diagrams, prototypes, and verification and test approach, computer modelling.
- Design coordination interface with Contract for VAC work & E&M works and other system wide contractors as per the requirement of scope of works for all equipment, interfaces, interlocks etc.

BMS/3.01.5. Software Requirements

PLC software shall conform to the CENELEC standard EN 50128. Software validation and verification shall conform to the IEEE Standards 1012-1998 and 1059-1993.

The Contractor shall demonstrate to the Employer's Representative the correct application of the standards specifically detailing the allocation of software integrity levels for all software. The Contractor shall submit with the Design Plan for the review of the Employer's Representative a list identifying all software that will be maintainable and re-configurable by the Employer.

BMS/3.01.6. Environmental

All BMS equipment shall operate correctly under the environmental conditions specified in the Employer's Requirements

BMS/3.01.7. Power Supplies

The requirements for the power supply of the BMS shall be coordinated with the E&M Contractor.

BMS/3.01.8. Design Documentation

The Contractor shall, in addition to the documentation requirements specified in the Employer's Requirements, supply, as a minimum, the following hardware and software design documentation:

- Final design specifications, details and drawings.
- Interface design documentation.
- The submission of the above documentation shall be included in the Submission Programme specified in Employer's Requirements .

BMS/ 4.00 BMS Central Hardware

BMS/4.01.1. Central Processing Equipment (Work Station)

The central processing equipment shall comprise one high performance real time, digital personal computer, rated with such application, complete with keyboard and mouse, one colour graphic VDU, system printer(s) to log all transaction and alarm printer(s). All the equipment shall be suitable for the power supply voltage of 230VAC +-6% 50Hz +-2%.

The central equipment shall be located where shown on the plans and shall meet the following minimum criteria:

BMS/4.01.2. Personal Computer

The Work Station shall be a personal computer (PC) **commercial grade Desktop, latest** Configurations as per BOQ.

The Work Station color monitor shall be 18.5-inch diagonal nonglare flat LCD screen and has minimum resolution of 1280 pixels horizontal, 1024 lines vertical and minimum contrast ratio of 700:1.

Work stations shall include all accessories needed to comply to UL requirements.

Further, all accessories shall be included to satisfy the local authorities having jurisdiction over the system. UL listed cards (originals preferred or photocopies) shall be provided to support the documentation that such listing is in effect.

BMS/4.01.3. Notebook PC

The sub-contractor shall provide a colour note book for use as a portable programming tool. The colour notebook shall have a high quality colour with latest configurations as per BOQTo ensure hardware quality, computer clones shall not be acceptable.

BMS/4.01.4. Printers

The sub-contractor shall provide printers as specified for recording alarms, operator transactions and system reports. To ensure hardware quality, printers shall be internationally branded, warranted, and technical support, spare parts and consumables should be freely available from the manufacturers authorized distributors.

The first printer shall be assigned for trend log, summary, totalizer logging, recording alarms and providing system reports. The second printer shall be a colour printer that support screen graphic output and can always be configure as an alarm output printer when the alarm log printer is out of order. Each of these printers shall be inter-changeable, and shall have the following characteristics:

BMS/4.01.5. Dot-Matrix Printer

- 132 column/300 character per second print speed.
- 24 pins dot matrix character structure switchable to 29 x 23 dot matrix for letter quality output with 96 ASCII upper/lower case character set.
- Software selectable under, emphasized, double strike, and expanded (double width) characters capability.
- Adjustable line spacing of six or eight lines per inch with compressed mode option for 220 characters/line and bidirectional printing and logic seeking.

BMS/4.01.6. Network Switches, Modems, Hubs, Gateways

All modems, hubs, switches, gateways and other serial equipment to be used in the application of system networks must be of industrial grade quality to meet the following criteria:

- Are designed for industrial environments
- Can tolerate up to 0 to 40 C
- Can tolerate 5-90% humidity
- Withstands power surges
- Provide easy DIN-rail mounting
- Are powered directly from 24 VDC/230 V
- Are designed for longer MTBF

BMS/ 5.00 TVS PLC Design - Control and Monitoring

BMS/5.01.1. General

The Contractor shall provide necessary hardware, software, data, etc., so that the control and monitoring functions for the TVS can be performed.

BMS/5.01.2. TVS Control and Monitoring Facilities

The Contractor shall develop operating scenarios for the TVS for normal, congested and emergency situations and shall provide control sequencing to provide for safety of equipment and passengers during emergency situations especially during evacuation of passengers.

The TVS PLC shall be completed and equipped with provisions for automatic, manual, local and remote controls so that the fans & motors can be operated from a remote terminal at the Operations Control Centre (OCC), a local terminal at the Station Control Room (SCR), manually at a Ventilation Control Panel at the Station Control Room (SCR), manually from the a Local Control Panel at the TVS Plant Room.

Upon loss of control power, TVS PLC components shall automatically operate as described for emergency conditions.

Temperature monitoring will be included by the Contractor as provided in each running tunnel as applicable.

BMS/5.01.3. Control System Interfaces

The control system for the TVS to be provided by the Contractor shall comprise of a Local Control System that shall interface with the other systems to be provided by other Designated Contractors

The TVS and ECS will normally be controlled and monitored from the OCC. At OCC, a Supervisory Communications and Data Acquisition System (SCADA), will control and monitor the TVS plant in each station ancillary building such that they are normally unattended locally.

The local control system for the TVS shall be designed to receive control commands from OCC, to control the TVS equipment to the desired conditions and report equipment status, including operation alarms, to the OCC via SCADA, Ventilation Control Panels (VCP).

BMS/5.01.4. Equipment for BMS Interface

Volt-free contacts provided shall comprise a pair of contacts operated directly by the equipment but electrically separated such that no potential derived from the equipment appears at the contacts. Volt-free contacts shall be used to complete external alarm or indication circuits with the supplies for these circuits being obtained from an external source. For the equipment to be controlled by the BMS, the BMS will transmit a voltage pulse signal of required voltage to termination block. There shall be one interface for control open and one for control close operations. The Contractor shall provide appropriate equipment to sense and latch the voltage pulse signal for performing the open/close control function. The BMS digital output (DO) signal shall be as stipulated.

For the Life Safety equipment to be monitored by the BMS, the BMS will transmit a positive voltage pulse signal each for On/Off, Healthy/Fail, Open/Closed etc., as appropriate.

Volt-free contacts shall be readily convertible from NO to NC and vice versa by simple field adjustment. Contacts shall be rated to adequately make and break and carry continuously not less than 5 A at 230 V AC or 2 A at 24 V DC.

BMS/5.01.5. System Components

The Local Control System components for the BMS shall comprise:

- External interface with the SCADA to facilitate system-wide control & monitoring of the TVS,ECS,E&M equipment at OCC.
- External interface with the fire protection systems for activation of the trackway exhaust fans for station platform level fires or shut down of respective TVS equipment.
- Local Programmable Logic Controllers (PLC).
- Interfacing with the Motor Control Centres (MCCs).
- Ventilation Control Panels (VCP).
- Remote I/O units for interfacing with Electro/Pneumatic Panel for the compressed air system for the automatic dampers. (If pneumatic damper actuators are opted for by the Contractor)
- Sensors and field devices.
- Programming and Maintenance (PM) terminals.

BMS/5.01.6. Control and Monitoring at Operation Control Centre (OCC)

The control and monitoring of the TVS equipment at the OCCs shall be via the RTU/REDUNDANT SERVER's provided under this contract.

The Contractor shall provide the data necessary so that the following functions can be performed by the SCADA at the OCCs:

- To provide operating command modes and set points to the PLCs.
- To provide individual or group start/stop and indicate status of TVS equipment.
- To provide centralised logging of selected TVS equipment including periodic reports on usage as well as program maintenance guides.
- To indicate and log alarms such as high temperatures, equipment fault/failure, etc.
- To provide Daily Report, Weekly Report, Monthly Report of total energy consumption and Operating Hours Report of all TVS equipment.
- To indicate and log the operating status and alarm conditions of the TVFs, TBFs, UPEFs, TEFs and their associated dampers, tunnel ventilation system bypass and isolation dampers, MCCs and emergency stop push button.
- To provide remote control for the TVFs, TBFs, TEFs and their associated dampers.

BMS/5.01.7. Control and Monitoring at Station Control Room (SCR)

The Contractor shall provide necessary hardware, software, data, etc., for each station so that the following control and monitoring functions for the TVS can be performed:

- To initiate operation of the tunnel ventilation system from the OCC in response to train congestion operations resulting from a delay or operational problems which prevents the free flow of trains through the system. When a train stops in a tunnel due to congestion on the running line and when the tunnel temperature rises above a pre-set value, the relevant TVS operation mode shall be activated by a command from the SCADA, which is referred to as the “Demand Signal”. The Demand Signal will be provided by others through the SCADA.
- To initiate operation of the TVS in response to emergency operations which generally result from a malfunction of the train on track. An emergency may include major disruptions such as a train on fire requiring passenger evacuation. The TVS control system shall enable the OCC operator to quickly activate the appropriate operation mode of the TVS plant for emergency ventilation of the tunnels or trackways, e.g. to direct smoke away from the evacuation path during fire emergencies.
- To initiate operation of the TVS to provide adequate ventilation in the tunnels during traffic block period (non-revenue period).

BMS/5.01.8. TVS System Back-up

To provide back-up for the operation of the TVS in the event of failure of automatic control of the SCADA, the following additional provisions shall be provided:

- Manual activation of the congestion and emergency operation mode from the VCP in the Station Control Room.
- Manual operation of the individual TVFs, TBFs and TEFs from the OCC.

BMS/5.01.9. (Local) Programmable Logic Controller (PLC)

This is located in the TVS Control Rooms of each station to maintain the normal operation of the TVS at the stations. One or more PLCs shall be provided in each of the TVS Control Rooms at both ends of each station to control the associated TVS equipment. The Contractor shall provide the necessary interfacing and redundant communication links between the PLCs at both ends of each station to perform the interlocking, control, operation and monitoring functions and requirements for the TVS equipment.

Principal functions of the PLCs shall include but not limited to the following:

- To receive commands from the SCADA and perform sequential starting of the equipment with an adjustable pre-set time delays to avoid excessive surge on the power supply system during starting of the equipment.
- To monitor the status and alarm indications of all TVS equipment and provide automatic changeover to the standby or idling equipment whilst retaining flashing indications for the malfunctioned equipment at the Local Controls. The PLCs shall be able to activate or reset buzzers at the associated Local Control Panel upon alarm condition.
- To monitor the status and alarm indications of all TVS and associated equipment and report any change of status to SCADA and the Programming and Maintenance (PM)

terminals.

- To perform automatic start-up of the TVS plant in the morning and shut down at night.
- To receive from and send data to SCADA.
- To receive digital status such as the "ON/OFF" or alarm status of equipment.
- To directly control the starting/stopping of the TVS equipment and opening /closing of the associated dampers.
- To output analogue signals in the form of voltage or current (0-10V, 4-20 mA) to the transducers in the control device panel of the equipment where they are converted into suitable signals to drive the actuators or other control device such as valves.
- To receive analogue signals in the form of voltage or current (0-10V, 4-20 mA) from field sensors, convert these signals into Engineering units and reporting them to the SCADA.
- To log and report alarms of analogue signals which have exceeded pre-set high/low or rate of change limits.
- To receive set-point information from the SCADA and PM terminals during initialisation or up dating and store these set-point values in the memory for control reference and function.
- To receive operation mode commands from the SCADA and operate the fans and dampers in a pre-set configuration with insertion of time delays and interlocking logic.
- To monitor the activation of the push buttons or switches on the VCP, and LCP and execute priority control.
- To automatically restart the TVS equipment when power to TVS plant is restored after a power failure or interruption, sequentially without causing the MCC circuit breakers to trip.
- To provide the interlocking functions required for the TVS and AHU equipment during operation in the TVS Closed System Mode
- To automatically start the standby TVS equipment and their associated equipment and dampers upon detection of failure of the TVS and ECS equipment.

BMS/5.01.10. Technical Requirements of Programmable Logic Controllers (PLCs)

BMS/5.01.11. General

PLC’s shall be supplied by a manufacturer of international repute with a proven track record of similar installation applications.

PLC configurations shall be completely modular, DIN rail mounting, and compact in construction to ensure maximum optimsation of cabinet space without compromising environmental operating conditions. There shall be a range of expansion I/O modules available for different signal requirements such that a vertically integratable cost/performance configuration is realized for each location.

PLC's shall be supplied and installed for monitoring and controlling equipment that shall consist of:

- A microprocessor based processor (CPU)
- Input and output interface modules suitable for a mixture of digital, analog and pulse inputs and outputs.
- Power supply and internal battery back-up equipment.

BMS/5.01.12. Functionality

The PLC shall perform the following functions:

- Cyclical measurement of the state or value of each input signal.
- Cyclical, uninterruptible execution of software, which performs functions according to a predetermined sequence, or programme.
- Cyclical and regular update of its output according to the results of those computations.

BMS/5.01.13. PLC Processor

The PLC processor shall a multi tasking, multi CPU architecture with capability of solving complex mathematical functions.

The PLC Processor shall have extensive diagnostics, and should have the capability to monitor and detect faults in Individual channels of I/O modules.

All the Modules of the PLC platform should have the capacity to be inserted and removed under fully powered up conditions, including the CPU Module.

The Power Supply Modules of the PLC platform should be able to source the Interrogation Power Supply directly from the In Rack Power Supply.

The PLC processor can either have an 100 MBPS Ethernet Processor or have the ability to configure an Ethernet Interface Module to it, either of which shall conform to all the specifications listed in this document. The protocol used over Ethernet shall be Modbus over TCP/IP or Ethernet IP.

The PLC should have the capacity to be monitored over an Ethernet network.

The PLC processor shall be able to monitor its resident I/O while also being able to communicate with a SCADA network over an Ethernet network.

The processor shall as a minimum should have following on-board memory:
• 2 × 2 MB flash for the system and application program.
• 2 × 512 kbyte SRAM with battery backup (for IO, markers, counters, timers and registers).

• 2 × 512 kbyte SRAM for data-exchange with the other Control Processor.

The PLC Processor shall have dedicated processing capabilities for deterministic processing of analog loops

The PLC processor shall have a built-in serial port or RS 485 Modbus port and the ability to add additional serial ports that can be configured communication.

The PLC processor shall have the ability to receive and map signals from third party systems but in particular from the Fire Alarm System over Modbus RS 485 protocol/BACnet IP/Ethernet IP.

The processor serial port shall be suitable for connection to any other devices that can send and receive ASCII characters and communicate using MODBUS protocol characteristics.

The processor should be able support data transfer and remote programming for standard applications in addition to peer-to-peer communications between other processors and devices, on the Ethernet network.

It will be possible to connect a single industrial terminal to the port to program the respective PLC processor with either on-line or off-line capabilities.

The PLC processor will have a configurable memory with state of art hardware. (utilize up to 65% of its original capacity)

- < 512 I/O Count 1.0 MB Memory
- up to 1024 I/O Count 2.0 MB Memory
- up to 2048 I/O Count 4.0MB Memory
- up to 3072 I/O Count 8.0 MB Memory

The PLC processor will have the capability to support one of the following language structures:

- Structured Text
- Sequential Function Charts
- Ladder Logic
- Function Block

The processor shall support the Advanced Instruction Set that includes basic and advanced ASCII string instructions, and advanced math functions.

The processor shall support a system protection environment with passwords and privileges and support a form of backup communications module.

The PLC system shall be designed fail-safe, in terms of operating logic. A “1” logic signal is considered to be normal state, and a “0” logic signal is the trip state. Logic output signals are to fail to a “0” state on power failure, or on component failure.

The PLC System shall be a Fail Safe Control, Programmable Logic Controller (PLC) based with a Quadruple Modular Redundancy (**QMR**) system architecture.

. The system shall not have any time limitations to work under degraded mode. The same shall be demonstrated in TUV report and safety manual.

BMS/5.01.14. PLC Interface Modules

The following hardware described will interface to the field mounted sensors and equipment for control and monitoring.

Digital inputs:

- **Volt Free contact (Normally Open/Close)**

Digital Outputs (relay):

- Volt-free contact, 24 VDC, 30 VA

Analog inputs:

- 0-10 VDC, 4 -20 mA with electrical isolation from ground
- >60dB interference rejection at 50Hz

Analog Outputs:

- 0-10 VDC, 4-20mA

Pulse Inputs:

- 12 VDC, 24 VDC up to 10 pulses/sec (2kV isolation)

Serial Link:

- RS 485, / V24,

BMS/5.01.15. PLC Hardware Requirements

PLC Operating Voltages: The PLC must be able to operate at 100% from the following power sources:

- 110 VAC - 230 VAC
- 24 VDC - 110 VDC

Note: The PLC must operate at the nominal supply frequency of 50 Hz with a 15 % variation.

BMS/5.01.16. PLC Programming

The PLC shall be programmed with manufacturer proprietary software, IEC 1131.3-compliant, mixable and reversible List language and Ladder language. The software shall features Windows-based editing functions and integrated online help.

An original copy of the latest manufacturers proprietary software shall be provided to JMRC upon completion and handover together with all generated site specific data.

BMS/5.01.17. PLC Additional Features

The PLC shall offer the following additional features as a minimum:

- Fast up/down counters
- Time delays

- Permanent data backup
- RS 485 Modbus master (primary)/Slave (secondary) communication, Control net, Ethernet or Modbus, and interaction with third party devices.
- 24 VDC power supply modules.
- Modular, Expandable I/O modules (24 VDC input, transistor or relay output)
- Modularity: 8, 16, 24.32
- Signal type: discrete, analog or mixed, removable
- High-density connectors
- Easy-to-wire system
- Program capacity of up to 8000 list instructions
- Options shall include a built-in display screen, memory cartridges, a real-time clock and communication adapters.

BMS/5.01.18. Not Used.

BMS/5.01.19. Environmental Conditions

The PLC must be able to operate in the following conditions:

Operating Temperature	0 to 55°C
Storage Temperature	-25 to 70°C
Relative Humidity	5 - 90 % (without condensation)
Operating Shock	IEC 60068-2-27
Vibration Resistance	IEC 60068-2-6;

Conforms to the relevant standards for PLC’s.

BMS/5.01.20. PLC communications

Although the PLC processor specified above will have the capability of communicating directly with a SCADA system via Modbus over TCP/IP protocol or Ethernet IP, the primary SCADA interface shall be via the SCADA interface termination panels detailed in this Specification. In addition to the above, the PLC shall have the capability to be monitored directly using the Ethernet IP.

The Contractor shall supply a SCADA interface termination panel for each item of mechanical plant and equipment as detailed in this Specification, including mechanical plant and equipment incorporating PLC control systems.

BMS/5.01.21. Not Used.

BMS/5.01.22. PLC Panel Internal Wiring

Control panel, switchboards and distribution boards wiring shall be clearly identified in accordance with the Definitive Design Drawings using cable core markers. Cable core markers shall read left to right or top to bottom.

Wiring shall be enclosed in metal ducts or neatly loomed with nylon ties or spiral binding as required. Wiring ducts shall be filled to a maximum space factor of 50%.

Where wiring is required to connect to devices mounted on doors it shall be arranged such that opening and closing of the door is not impeded whilst minimising flexing of the wiring loom. The loom shall be effectively fixed at both ends of the door opening with insulated saddles or clamps.

Wire colours shall comply with the following requirements:

Phases	Red, Yellow, Blue
Neutral	Black
AC Control	Grey
DC Positive	Orange
DC Negative	Lilac
Earth	Green with Yellow trace

Terminals shall be clearly numbered, and shall be rail mounted, adequately sized to suite wiring size and provided with 20% spare rail space. The bridging of terminals shall be provided by the use of terminal bridging links as supplied by the terminal manufacturer.

Control wiring shall be terminated using pre-insulated pin or spade type crimp lugs. Conductors terminating to study type terminals shall be fitted with spade type crimp lugs.

A separate earth bar shall be provided for the termination of all earth wires. Only one wire shall be connected into each termination point.

Minimum conductor size shall be 0.7 sqmm.

Cable glanding plates shall be earthed directly to the control panel earth bar.

Panels shall be fitted with a suitable pocket to contain circuit diagrams and other relevant Definitive Design Drawings. An “as installed” set shall be provided with the panel.

A maximum of two control wires shall be terminated on any control device terminal.

HRC fuse links fittings shall be of the bolt in type and shall be installed in fully shrouded fuse holders. 415V fuses shall be high interrupting capacity type complying with the relevant standards.

All internal wiring shall be neatly run and securely fixed in non-metallic LSZH cleats in such a manner that, wherever practicable, wiring can be checked against diagrams without removal of the cleats. Wiring passing out to fully accessible positions shall be run in non-metallic low smoke halogen free flexible tubes or conduits.

BMS/ 6.00

BMS/6.01.1. ECS Control and Monitoring Facilities

The ECS equipment shall be monitored and operable from the local ECS panel, ventilation control panel in the station control room and also some designated commands and the indications from the OCC through SCADA. Necessary provisions to be made in the station for enable OCC to monitoring and control. The communication line from station to OCC shall be provided by the designated contractor.

BMS/6.01.2. Trackway Exhaust Systems

During normal conditions, trackway exhaust fans shall operate continuously. In addition, control of these fans shall be possible during congested and emergency conditions for the purpose of aiding tunnel ventilation systems in trackway temperature control and providing additional smoke removal capability for the station and tunnel.

BMS/6.01.3. Smoke Extract System

The ECS &TVS system should have features of adequate smoke control and extraction. The smoke control should be suitably designed to control spread of smoke in case of fire.

BMS/6.01.4. Station air conditioning systems in an Emergency

During an emergency fire condition within a station, the station air handling system shall be operable as a smoke removal system to supplement the smoke extraction system

BMS/6.01.5. TVS Architecture

TVS BMS architecture shall consist of programmable logic based electronic processors with redundant configuration at processor, communication and power supply level. Each processor will perform self-diagnostics in the background and have alarm indicators for hardwire failure. The processors will be capable of detecting any malfunction in other modules and report this to the workstation. PLC processors, communication modules and power supply are housed in a single cabinet along with I/O modules serving each station end TVS equipment.

The processor will have indicator lights for “Running” status, “Online/Standby” status, “Communication Failure” alarm, I/O force status & Battery status. Each processor will have independent facilities of power on/off, system reset, and diagnostic indicators.

Each processor will have a resident real time clock with a battery back up. It will be synchronized with clock signal from the Workstation for various operations. All processors will be able to communicate to each other without workstation.

The PLCs will be able to continuously operate under the following environment conditions:

Operating temperature: 0 to 60 deg. C

Storage temperature: -40-deg. to 70 deg. C

Relative humidity: 5 to 95% (non-Condenser)

BMS/6.01.6. Processor redundancy

Two identically- configured PLC processors are connected in a “Hot Standby” arrangement as “Master” and “Standby” so that when a component of the Master PLC fails, the standby PLC will take over automatically without interrupting the plant operation. The two PLCs communicate with each other over Modbus communication bus or Fiber optic.

Operating Principal

The redundant system shall provide streamlined transfer of I/O control from Master processor to Standby processor upon the failure of Master processor without using any relay circuits.

Each PLC shall have a customized program for redundancy programmed into its user logic, which communicates status information between the two PLC processors and exchanges the state RAM. Upon a power-up, whichever processor beats first will be assigned as master/primary. It shall remain master/primary as long as standby processor finds it healthy. In case standby processor senses that Master/primary has failed, it will force the changeover irrespective of how Master/primary sees itself. This shall avoid total reliance on processor’ self-diagnostics for changeover.

The Master/primary processor shall run the application by scanning user logic and operating distributed I/Os. At the end of every program scan, the Master/primary processor shall send input / output data and internal data tables to the standby processor, so that in the event of changeover, the two processors will have the same data. Both the processor should run in sync mode, data should be same in both the processor at any moment of time to make the changeover bump less. Manual programming should not be required for Hot Backup.

Changeover

The automatic changeover time of control from one PLC to the other PLC includes time required for following events

Failure detection

Time to confirm failure

Time to confirm availability of the standby system

Time to switch over, and

Time to confirm success of switching over.

The standby shall be ready to assume control within one scan in case of failure of Master/primary. Master/primary & Standby/Secondary states shall be switch-able. Each Processor can be put into the Master/primary state, but to do this the other must be in standby Secondary state.

Should a fault occur in the Master/primary processor, control will be transferred to standby processor in maximum 500 ms. During the changeover, PLC outputs shall be maintained in their last state until they come under control of the standby/ Secondary processor. Fault data is sent to workstation for reporting the processor failure. The system shall now recognize earlier standby processor as Master/primary processor.

BMS/6.01.7. Communication Redundancy

The processors communicate with each other and with I/O modules on redundant communication bus. The communication speed between processor and I/Os shall not be less than 5Mbps.

BMS/6.01.8. Power Supply Redundancy

Each TVS PLC outstation has two 24Vdc power supplies arranged in a redundant configuration. These power supplies are used for powering up the processors and I/O modules.

BMS/6.01.9. Network Connections

Each processor provides a serial port for local connection to a programming device. Other network connections such as Ethernet and serial RS 232 port are also provided for communications to the Workstation. Other communication such as control net or Ethernet shall also be provided to the workstation

One processor of redundant configuration shall be connected to SCR room Switch and the other processor shall be connected to TER room Switch. The two switches are connected to each other via a dedicated LAN. The communication link to PC and OCC are Modbus on TCP/IP or Ethernet IP.

OCC SCADA will interface with both SCR and TER room switch, while workstation will interface only at SCR room switch.

Network links

The system architecture shall use the following communication routes as applicable:

1.	PLC (Master)	-	PLC (standby)	on Modbus Plus/Ethernet/IP
2.	PLC	-	I/O	on Modbus Plus /Ethernet/ IP
3.	PLC	-	VCP I/O	on Modbus Plus /Ethernet/ IP
4.	PLC	-	TVS Repeater I/O	on Modbus TCP/IP /Ethernet/ IP

5.	PLC	-	SCR Switch	on Modbus TCP/IP/ Ethernet /IP
6.	PLC	-	TER Switch	on Modbus TCP/IP/ Ethernet /IP
7.	SCR Switch	-	Workstation	on Modbus TCP/IP/ Ethernet /IP
8.	TER Switch	-	Workstation	on Modbus TCP/IP/ Ethernet/ IP
9.	SCR Switch	-	OCC	on Modbus TCP/IP/ Ethernet IP
10.	TER Switch	-	OCC	on Modbus TCP/IP/ Ethernet IP

Alarm

If a network link fails, the system shall have inbuilt programs within the processors which will generate fault bits available to workstation and OCC. The communications error rate will be logged and stored in the processor. If the error rate exceeds the set point, an alarm will be sent to OCC.

BMS/ 7.00

BMS/7.01.1. Tunnel Ventilation System Control Design

Tunnel Ventilation system provides tunnel ventilation and air movement control over the tunnel area at the station. Two large diameter, reversible tunnel ventilation fans are installed at each of the east and west end tunnel ventilation plant rooms. These fans shall operate to provide forced ventilation in tunnels during the congestion and emergency mode. Supply nozzles in one end are used to maintain required thrust into the tunnels. Fixed speed reversible Tunnel Booster Fans are provided at other end station. Draft relief, tunnel ventilation and nozzle discharge dampers provide airflow in supply or extract mode.

Though the complete plant comprising of Tunnel Ventilation Fans and Tunnel Booster Fans, Draft release dampers, Tunnel Ventilation dampers, Nozzle dampers are dedicated to individual tracks, it shall also be possible to use the tunnel ventilation fans as standby to other fan in that plant room in case of failure of the dedicated fan. However, the concept of runtime based duty/standby selection/changeover shall not be applicable to these fans.

During extract mode, nozzle dampers of associated track shall remain open to provide partial airflow through them.

All reversible fans shall be able to accept the direction reversal command without any time delay. Any cool down period or other delay timers shall be built in the MCC Electrical design for these fans.

The TVF require to operate in reverse direction can operate only in open loop.

BMS/7.01.2. System Operation Mode

The Tunnel Ventilation system operation can operate in the following modes:

1. Manual Mode
2. Normal Mode
3. Congested Mode
4. Emergency Mode

Manual Mode

During manual mode the system shall be under direct control of an operator at MCC or LCP. An operator shall operate the system via push buttons provided at each equipment control section of MCC.

Normal Mode

During normal mode, train movement in and out of tunnel provides ventilation.

This ventilation mode may work in open loop or closed loop. These loops are similar to 100% Fresh Air and Re-circulating mode of the ECS system.

During open loop, draft relief dampers and shaft dampers shall open providing air exchange with the atmosphere.

During closed loop, draft relief dampers and shaft dampers shall close facilitating air exchange between the tunnel and the station ECS.

Congested Mode

When OCC decides a particular tunnel to be in congestion mode, an operator shall be able to command the ventilation system to work either in open loop or closed loop congestion mode. Decision to run in open or closed loop will depend upon the prevailing mode in station ECS. However, an operator shall be able to manually cause the system to run in a control loop different to prevailing control loop at the station. In such cases, station ECS shall also assume the control loop selected by the operator. The ECS and TVS shall remain in selected control loop till Operator commands the system control loops to work in auto.

The tunnel ventilation system shall be normally controlled to supply the air inside the tunnels along the direction of train travel before it stopped. However, the tunnel ventilation system may run in opposite direction in case one or more equipment have failed making the system unavailable in the desired mode. An operator with valid password and access levels shall be able to take such decisions.

Once OCC commands to start the TVS, PLC will perform the required logical operations as follows:

Control Loop	**Train Location**	**TVF Fan Direction**	**TBF Fan Direction**
OPEN	Out of station	Supply	Supply
	In the station	Reverse	Reverse
CLOSE	Out of station	Supply	Supply
	In the station	Rest	Rest

Rest indicates the equipment at that station end shall not operate.

Emergency Mode

The workstation shall gather information related to fire and transmits to OCC for verification. The workstation shall not take any preventive measures automatically. When the OCC shall decide a particular tunnel or station area to be in Emergency mode, an operator shall be able to command the ventilation system to work either in forward, or reverse direction.

Upon receipt of an emergency command, the station ECS and TVS shall assume the open loop status irrespective of prevailing mode in station. The ECS and TVS shall remain in open loop till operator commands the system modes to work in auto.

The decision to run the tunnel ventilation system in forward or reverse shall be based on the evacuation path and shall be taken by an operator. The TVS with shorter evacuation path will be controlled to supply the air inside the tunnels. However, tunnel ventilation system may run in opposite direction in case one or more equipment have failed, making the system unavailable in desired mode. Such decisions shall however be taken by the Operator with Valid password and access levels.

BMS/7.01.3. Tunnel Ventilation Fan

Following monitoring and control points are considered for Tunnel Ventilation Fan:

a. Control of Fan on/off; Forward/Reverse direction run command

b. Monitoring of Fan running status, airflow, FID open/close position

c. Monitoring and Alarms for Emergency Stop Button, Fan local/remote status, Fan trip, current, vibration sensors

Tunnel Ventilation fans can be run in following directions based on open or close loop situation:

Forward Direction Open Loop

Once PLC receives a command to operate the fan in forward direction in open loop, following events shall occur:

a. The PLC shall command the nozzle damper and shaft damper to open, draft relief damper and return damper to close.

b. The PLC shall wait for a predetermined time for dampers position confirmation by their limit switches.

c. Once the dampers are confirmed to be in desired state, the PLC shall command the fan to run in forward mode. Fan isolation damper is hardwired in MCC to ensure that it opens before the fan runs.

d. If the fan fails to run, the PLC shall disable the fan control circuit and command another fan to run. An alarm shall be generated at workstation.

e. If both fans fail to run, the PLC shall disable both fan control circuits. An alarm shall be generated at workstation.

f. If the nozzle damper or shaft damper fail to open, the TVF shall shutdown.

Forward Direction Close Loop

Once the PLC receives a command to operate the fan in forward direction in close loop, the following events shall occur:

a. The PLC shall command the nozzle damper and return damper to open, draft relief damper and shaft damper to close.

b. The PLC shall wait for a predetermined time for dampers position confirmation by their limit switches.

c. Once the dampers are confirmed to be in desired state, the PLC shall command the fan to run in forward mode. Fan isolation damper is hardwired in MCC to ensure that it opens before the fan runs.

d. If the fan fails to run, the PLC shall disable the fan control circuit and command another fan to run. An alarm is generated at workstation.

e. If both fans fail to run, the PLC shall disable both fan control circuits. An alarm is generated at workstation.

f. If the return damper fails to open, the TVF shall shutdown.

Reverse Direction Open Loop Only

Once a PLC receives a command to operate the fan in reverse direction in open loop, the following events shall occur:

a. The PLC shall command the nozzle damper, shaft damper and return damper to open, draft relief damper to close.

b. The PLC shall wait for a predetermined time for dampers position confirmation by their limit switches.

c. Once the dampers are confirmed to be in desired state, the PLC shall command the fan to run in reverse mode. Fan isolation dampers are hardwired in MCC to ensure that they open before the fan runs.

d. If the fan fails to run, the PLC shall disable the fan control circuit and command another fan to run. An alarm is generated at Workstation.

e. If both fans fail to run, the PLC shall disable both fan control circuits. An alarm is generated at Workstation.

f. If the nozzle damper or return damper fails to open, the TVF shall not be shutdown.

BMS/7.01.4. Tunnel Dampers

The following monitoring and control points are considered for Tunnel Vent, Draft Relief, Shaft and Nozzle Dampers

a. Control of Damper open/close

b. Monitoring of Damper open and close position

c. Monitoring of damper local/remote status

PLC will operate these dampers as per mode table.

BMS/7.01.5. Track way Exhaust Fan

There are three Track way exhaust fans on each side of station. These fans shall normally work as part of station ECS system. Accordingly, these shall be switched on/off along with the AHUs. **However, during emergency mode, track way exhaust fan shall operate from TVS system.**

The following monitoring and control points are considered for Track way Exhaust Fan:

a. Control of Fan on/off;

b. Monitoring of Fan running status, airflow, FID open/close position

c. Monitoring and Alarms for Emergency Stop Button, Fan local/remote status, Fan trip, current, vibration sensors;

Fan isolation dampers are hardwired in the MCC such that damper opens before a fan can start. In all such cases, Open/close indications of dampers through limit switches shall be hardwired in MCC. MCC shall also provide repeat signals to BMS for the status indication of dampers.

BMS/7.01.6. Tunnel Temperature Monitoring

One temperature sensor on each track at each end of tunnel shall be installed by Vendor at pre-determined distances (minimum 30 mtrs) from station ends. These reading are sent to OCC to facilitate the tunnel condition monitoring.

BMS/ 8.00 SYSTEM INTERFACES - MECHANICAL

SCADA System Interface with Mechanical Systems

BMS/8.01.1. General

The Contractor shall ensure efficient interface and co-ordination with all other Contractors concerning mechanical works.

Interfacing between the TVS SCADA system and mechanical equipment will require co-ordination between the respective contracts as specified. The Contractor shall liaise to ensure the interfacing between each system meets the requirements of its respective specification.

BMS/ 9.00 SYSTEM INTERFACES - Fire Detection System

BMS/9.01.1. Initial Basis for Design

During the preparation of detail design the Contractor shall liaise with the designated Contractor, Employer's Representative, Jaipur Fire Services and other Designated Contractors to determine all requirements for response in event of fire, and then subsequently provide the necessary facilities. The initial design shall assume that all fans having a capacity in excess of 1 m^3/s shall be shut down by the fire detection system during smoke or fire conditions.

BMS/9.01.2. Works by the E & M Contractor

The E & M Contractor shall provide a complete fire-detection & alarm system including provisions for monitoring and control through a fire panel at station control room and OCC. This system shall have an interface for operation and control with other equipment such as ventilation / exhaust fans etc through TVS SCADA.

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BMS/ 10.00 SYSTEM INTERFACES - Electrical

BMS/10.01.1. SCADA Interfacing

Interfacing between the electrical system Contractors for providing monitoring and control of Electrical system required from OCC. The Contractor shall liaise with the Designated Contractor for the System-wide Works to ensure the interfacing between the mutual systems meets their joint and individual specification requirements.

BMS/ 11.00 PERFORMANCE REQUIREMENTS

BMS/11.01.1. General

Environmental Design Conditions: The outside air and station design conditions are given in the Employer's Requirements.

The TVS includes the TVFs, the TEFs and the TBFs.

BMS/11.01.2. Electro-Magnetic Compatibility

This Paragraph defines the minimum Electro-magnetic compatibility (EMC) requirements for all electronic and electrical equipment supplied under this Contract.

The Contractor shall co-ordinate with Project Contractors and ensure that the frequencies and bandwidths employed in the TVS/ECS PLC Systems will not fall into the frequencies known to be major sources of interference.

The Contractor shall ensure that the fundamental frequencies, harmonics and cross products produced by the TVS/ECS PLC Systems will not interfere with those of other systems in the Project.

The following standards and documents are applicable, in addition to the reference documents and other standards given in this document

- EU Directive on EMC (89/336/EEC);
- European Generic Emission Standard - Part 2: Industrial Environment EN 50081-2.

BMS/11.01.3. Equipment Mounting

Equipment to be mounted on the floor shall be placed on reinforced concrete equipment pads. Minimum pad height shall be 100 mm. The Contractor shall co-ordinate as necessary.

In cases where units are ceiling suspended, the support system shall be adequately braced to ensure stability during unit start up, operation and shut down.

BMS/11.01.4. Maintainability

Items such as knock out panels, double doors, lifting eyes, floor drains and access hatches shall be provided in the Contract. The Contractor shall co-ordinate as necessary.

Sufficient clear space shall be provided around equipment to facilitate equipment removal and replacement and to allow for ease in equipment servicing. Provisions shall be made for shaft, tube and filter pull space, access door swings and removal of miscellaneous components.

Control system schematic diagrams shall be posted in the vicinity of all control panels.

Piping system schematic diagrams shall be posted in each plant room.

BMS/11.01.5. Equipment Identification

Equipment, control devices, valves and piping systems shall be permanently labelled by the Contractor after installation. The labels shall conform to a system-wide method.

This method shall identify individual equipment items and provide information regarding equipment type, equipment function, flow direction and other such data as appropriate. Identification shall be keyed to the control and piping schematics.

BMS/11.01.6. General Safety Requirements

The following shall apply:

- All plant shall be fail-safe.
- Cables shall not be installed either exposed or surface mounted in air plenums that may carry air at elevated temperatures during fire emergency conditions.
- All conductors shall be enclosed in their entirety in armour sheaths, conduits, cable tray, boxes and cabinets.

BMS/ 12.00 INSTALLATION

BMS/12.01.1. Installation Plan and Program

The Contractor shall attend a weekly planning meeting with the Employer's Representative to finalize the work detail, commencing 4 weeks prior to the start of Installation on Site.

The Contractor shall submit a Construction and Installation Plan for the review of the Employer's Representative 90 days prior to the start of Installation on Site.

BMS/12.01.2. Method Statement

The Method Statements, as described in the Employer's Requirements shall be submitted to the Employer's Representative for review at least 30 days prior to the installation activity commencing On-Site.

BMS/12.01.3. Contractor's Resident Staff

The Contractor shall ensure that a qualified Representative is available on-Site for the duration of the On-Site Works during normal working hours and on-call to arrive on Site within 30 minutes at all other times.

The Contractor's Representative shall have sufficient authority to progress the Contractor's work on Site.

The Contractor's Representative shall be competent and qualified to act on behalf of the Contractor, and provide upon request information that may include:

- Current progress of the Works;
- Planned work for the next 5 weeks;
- Audit and inspection reports;
- Health and safety information; and
- Documents and records pertaining to the Works.

BMS/12.01.4. Drawings and Records

BMS/12.01.5. General

The Contractor shall provide 3 copies of all drawings in A3 size, bound into circuit books.

The Contractor shall ensure that, at each equipment location, an as-built copy of the Site documentation is provided. This documentation shall include as a minimum:

- Circuit wiring book;
- Equipment mode tables; and
- Operation and maintenance manuals.

BMS/12.01.6. Circuit Wiring Book

The circuit wiring books shall include as a minimum the following information:

- Cubicle and rack profiles;

- Room layout;
- Interface and boundary schedules with Project Contractors;
- Through circuits;
- Power supply arrangement;
- Earthing & bonding arrangement; and
- Cable circuit information.

BMS/12.01.7. Cable Records

The Contractor shall ensure that the as-built cabling infrastructure is fully documented and accurate at the time of substantial completion of the Section. The documentation shall include:

- Schematic of the cable routes;
- Location of cable joints;
- Cable types;
- Installed dates;
- Test data; and
- Core plan indicating the circuit and function of each core.

The Contractor shall be responsible for adding to all of the Combined Services Drawings with cable installation details and the timely supply of these marked up drawings to the Employer's Representative for overall co-ordination.

BMS/12.01.8. Earthing

The Contractor shall provide at each equipment room earth bars that shall be connected to the earthing system provided by Civil Project Contractors as shown in the Interface Specification. Two separate earthing points shall be provided, one for chassis and one for signal reference. The earth bars shall be used as common points for all earthing in that location. Please refer to the section on Earthing for installation compliance.

BMS/12.01.9. Asset Identification

The Contractor shall submit an asset database for review by the Employer's Representative. The database shall contain the complete asset listing for the Tunnel Ventilation System.

The database shall be designed with a minimum of the following information:

- Asset details;
- Failure history;
- Date installed; and
- Date tested.

All equipment and software, down to the line replaceable unit, shall have a unique identification number that is capable of being identified electronically and manually.

BMS/ 13.00 ELECTRICAL WORKS

BMS/13.01.1. General

The electrical works to be provided include but are not limited to:

- Provision of interlocks and protection schemes for the power distribution suiting to the to desired operation duly coordinated with high voltage side protections and that of the individual equipment.
- Provision of suitable schemes for connecting various equipment supplied for monitoring and control through SCADA and to the station control room. This includes supply of equipment / panels at station control room, at the plant room or at the equipment and its connections.
- Provision of automatic control of pumps, incoming supply, liquid level controllers or the equivalent arrangement for various pumping requirements.
- Furnishing all design, calculations, software programmes, drawings for appraisal of Employer’s Representative for consent.
- Establishing a detailed training and manpower development programme.
- Establishing testing procedure and acceptance criterion for manufacture/supply items/equipment and affording facilities for testing etc. at site and at the manufacturer’s premises.
- Provision of requisite lifting tools/tackles, spares and warranty and pre-commercial run operations for the equipment supplied.
- Provision of safety devices, charts, O&M manuals, checklists etc. as are necessary for safety of the workmen and as required under statutory regulations.
- These works shall be limited to station, tunnel, parking lots and other ancillary building associated with the project.

BMS/13.01.2. Coordination and Interfaces

The Contractor shall conduct interface and co-ordination with each System-wide Contractor to determine each Contractor’s requirements for the provision of fixings, openings, room sizes, installation sequences, etc. in order to prepare:

- Combined Services Drawings (CSD)
- Structural Opening Drawings (SOD)
- Structural M & E Drawings (SME)
- Coordinated Installation Programmes. (CIP)
- Equipment – General
- Equipment designation shall be numbered on plans, schematics, block and single-line diagrams.

- Numbers: Each piece of equipment shall be numbered according to the number of the circuit breaker feeding the piece of equipment. Terminal cabinets shall be numbered sequentially.
- Letters: Each equipment number shall be preceded by a letter designation as appropriate, as follows:

▪ Automatic Transfer switch	ATS
▪ Control Panel	CP
▪ Disconnect Switch	Z
▪ Fare Collection Power Panel	F
▪ Generator	G
▪ Lighting Panel boards, 415/240V	L
▪ Motor	M
▪ Motor Control Centre	MCC
▪ Motor Starter	MS
▪ Power Panel boards	P
▪ Supervisory Termination Cabinet (Marshalling Cabinets)	STC
▪ Switchboards	A
▪ Switchgear	SWGR
▪ Terminal Cabinet	TC
▪ Transformer	TX

BMS/13.01.3. Cables - General

All the BMS cables shall comply to the clause A16.3.20 and relevant sections in A 16 of ECS specifications. All BMS cables used outside the control panel shall be screened as per BOQ.

BMS/13.01.4. Raceway Material

Raceways may be of the following types:

- Galvanised rigid steel conduit
- Intermediate metallic conduit
- Fibre glass reinforced epoxy conduit
- Cable tray (galvanised rigid steel)

Materials manufactured for use as conduits, raceways, ducts and their surface finish materials, when installed in stations and trainways shall be capable of being subjected to temperatures up to 930o F (500°C.) for an hour, and shall conform to the National Electrical Code (NFPA 70). They shall also conform to the codes of the National Electrical Manufacturers Association (NEMA), the American National Standards Institute (ANSI), and

Underwriters Laboratories, Inc.

Materials manufactured for use as conduits, raceways, ducts and their surface, finish materials when used for emergency power circuits shall be strong and durable.

BMS/13.01.5. Line Section Design - Wayside Cables.

All cables shall be in conduit. In tunnels, the conduits shall be either attached to tunnel walls or directly buried. On elevated structures, conduits shall be attached to, or embedded in structure. Where the track is at ground level, the conduits shall be in concrete duct banks below grade or directly buried.

In tunnels and on elevated structures, a cableway shall be provided adjacent to the track. The top of the cableway (known as the serviceway) shall consist of removable covers suitable for walkway over. Maintenance personnel shall use the serviceway and no facility power cable shall be placed in the serviceway.

BMS/13.01.6. Wayside Duct Banks.

Duct banks shall be configured as required at the specific location. Manholes, pullboxes, junction boxes and cable vaults shall be spaced for ease of cable pulling, and shall meet applicable codes and operational requirements, without exceeding cable-pulling tensions. Underground duct banks shall be sloped towards manhole or box from which water may be drained or pumped. The design must be carefully coordinated with underground utilities to assure safe access within the right-of-way.

Bends in conduits within a duct bank shall be minimum 0.9m radius, regardless of size, and in conformance with manufacturer's recommendation.

Wayside duct banks, where used beyond tunnel sections shall be installed for pulling cables from the cableway in the tunnels to the points of terminations in the stations. To facilitate cable pulling, splicing, and transitioning, pull boxes shall be installed at intervals consistent with system requirements.

As directed in at-grade sections of the Depot, underground duct banks, prefabricated trenches, or direct burial cables shall be installed between adjacent tracks or in adjacent right-of-way. To facilitate cable pulling, splicing and transitioning, manholes or pull boxes shall be installed at appropriate intervals to accommodate the system requirements.

Cable transition details shall be shown on the drawings for at-grade to aerial structures and for at-grade to tunnel sections.

BMS/13.01.7. Conduit Transitions.

Conduit Transitions are needed when changing from one wayside cableway location or configuration to another and to provide conduit access from the wayside cableway to system wayside facilities, such as communication, fare collection, signals/signal systems equipment, traction power equipment, track switches, and tunnel emergency telephone stations.

Where conduit transition, pull or junction boxes, or manholes might collect water, means of drainage shall be provided.

BMS/13.01.8. Manholes, Pullboxes and Vaults.

Each manhole or pull box shall contain cable pulling irons, cable racks, ladder and/or rungs are required, and accessible ground rod. Aerial structure wireways of metal shall be individually grounded by means of ground cable(s) welded to the wire way every three meters and at intersections. The ground cables shall be extended to the nearest manhole or transition box at a station and connected to the station facility ground system. The manhole shall be designed such that the auxiliary power conduits can be divided from the system train control and communication conduits entering the manhole. Where possible, wayside conduits shall enter the manhole at the same elevation as those conduits on the wayside. Sudden changes in conduit elevations should be avoided in the vicinity of the cable vault.

A manhole or pull box shall be provided at the end of each facilities contract limit if no provisions have been made in the adjoining contract.

Manhole and pull box for access to under-platform area shall conform to the architectural requirements.

Cable vaults shall be used to integrate wayside duct banks with the station conduit system. The size and shape of these vaults shall be adapted to station configuration and shall include sufficient working room for a man and cable-pulling equipment.

BMS/13.01.9. Installation Considerations.

All electrical facilities conduit pull boxes, manholes, and so forth shall be installed on DMRTS right-of-way. If this is not possible, the additional required right-of-way shall be identified and co-ordinated with Employer’s Representative within 4 weeks after the notice to proceed has been issued.

Concrete-encased wayside duct banks shall have a 6.25 mm or a suitable minimum protective cover on all sides. Encased PVC and FRE conduits shall be coupled to GRS conduit before the conduit emerges from an encasement and becomes exposed. Conduits of dissimilar metals shall not be joined without insulating provisions to prevent galvanic corrosion.

BMS/13.01.10. Conduit Identification - Conduit Feeder Schedule.

The conduit schedule shall identify all feeder conduits to be installed, using symbols and annotations. Conduits that are to enclose circuits installed by others shall be clearly indicated. Installation specification shall require pull wire and permanent tagging of each conduit access.

Schedule Content.

Conduit and feeder schedules shall include the following information:

- Conduit identification – Conduit size
- Circuit identification – Conduit type
- Conduit from – Conductor description
- Conduit to – Conductor quantity
- Identification of multiple runs

BMS/13.01.11. Drawing reference

An indelible display shall identify the cables laid along with the conduits at each conduit junction / termination etc for identification during any future handling.

BMS/13.01.12. Design Approach

Raceway designed shall include all required runs between equipment and panel boards in electrical rooms, and so forth, and shall be shown on drawings with cross references to other drawings which detail the conduit routing in ceilings, walls or floor slabs as required. Conduits shall be extended from these secondary distribution points to associate equipment. Conduit runs which may exceed the 270-degree bend limitation and conduit runs in excess of 30m shall be detailed in the project drawings. Details shall include junction box locations, bends and potential obstructions, such as mechanical ducts and piping.

BMS/13.01.13. Cable Identification

Identification discs for cables installed within buildings or tunnels shall be supplied and attached with galvanised wire to each cable intervals not greater than 12 metres and at all cable terminations.

All cable ducts including spare ways are to be sealed at each end with a plastic compound or other approved sealing substance.

Cables used for control circuits and all multi-core cables having more than four cores shall be provided with cable core identification sleeves at their points of connection.

A display at the cable way / cable trench / cable gallery shall indicate the layout & identification of each cable. The display shall be indelible and weatherproof.

BMS/13.01.14.

BMS/13.01.15. Storage and Handling of Cables

Cable drums shall be stored on well-drained hard surfaces to prevent cable drums sinking and to simplify drum movements.

Cable drums shall be stored on battens placed directly under the flanges. Storage shall be in such a manner to leave sufficient space for air circulation. Every three months of storage the drums shall be rotated 90^{o} in the direction of the arrow.

During storage the ends of the cable shall remain properly sealed to prevent ingress of moisture.

Adequate shelter from rain and sun shall be provided. Adequate drainage shall be provided to prevent the cable drums standing in water.

Cable drums shall not be dropped during transit, and cranes employed during unloading. Cable drums should be rolled only in the direction of the arrow.

If passing one cable to another drum, the cable drum sizes must be the same.

During removal of the cable from the drum the minimum bending angle of 1 in 15 shall not be exceeded.

Pulling force when using stockings shall not exceed 9D in Newton (N) where D is the outer diameter of the cable.

For cables with pulling eyes, the maximum permissible tensile stress shall be 50N/sqmm, for aluminium conductor cables.

BMS/13.01.16. Tests

All the materials employed in the manufacture of the cable shall be subjected to tests specified in Indian Standards before manufacture of the cable.

After completion of manufacture and prior to dispatch the cables shall be subjected to type, routine & acceptance tests as specified in Indian Standards.

The guidelines for testing the cables or the accessories shall match or exceed the following tests as per relevant Indian or International Standards.

BMS/13.01.17. XLPE/ FRLS Tests

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- All Type tests as per A 16 of ECS specifications shall be provided

BMS/13.01.18. Cable Accessories

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Refer A 16 clause of ECS specifications

BMS/13.01.19. Packing and Marking

Packing - Cables shall be dispatched in wooden drums of suitable barrel diameter, security battened, with the take off end fully protected against mechanically damage. The wood used for construction of the drum shall be properly seasoned, sound and free from defects. Wood preservatives shall be applied to the entire drum.

Marking - On flange of the drum, necessary information such as manufacturer's name , type, size, voltage grade of cable, length of cable in metres, drum No., cable code, ISI certification mark, gross weight etc. shall be printed. An arrow shall be printed on the drum indicating the direction of rotation of the drum.

Drum lengths - Cables shall be supplied in drum lengths as follows:

- Medium voltage power cables up to and including 6 sq. mm - 1000 m.
- Medium voltage power cables from 10 sq. mm up to
- and including 300 sq. mm - 500 m
- Control cables- 1000 m
- Control cables
- A tolerance of + 5% shall be permissible for each drum.
- 5% of the order quantity can be supplied in non-standard lengths of not less than 100 metres.

BMS/13.01.20. Cable Trunking

Cable Trunking : Under floor, skirting, wall trunking and high level ceiling trunking shall be in accordance with the highest standards, shall be of the steel type with steel covers and shall be hot dip galvanised or zinc plated finish.

The lengths of trunking, bends tee sections and offsets shall be coupled together by means of fish plates and the trunking manufacturer's cadmium plated steel set screws, nuts and shake proof washers.

At each joint in the trunking continuity shall be maintained by means of copper links secured by brass nuts, locking washers and bolts.

BMS/13.01.21. Cable Tray

Cable tray shall be perforated full wrap around type not less than 1.5-mm thickness mild steel hot dip galvanised finish.

The cable tray shall be of sufficient width to take the cables without crowding and shall allow for future additions to the proportion of 25% of present requirements. Double stacking of cable shall not be allowed except where specifically agreed by the Employer's Representative.

The cable tray shall be fixed to purpose made galvanised steel brackets secured to the structure. The brackets shall be hot dip galvanised. Acceptance tests for the safe carrying load for each bracket at typical locations shall be established by the Contractor for the Employer's consent.

The fixing brackets shall rigidly support the cable tray and shall provide a clear space between the structure and/or obstructions and the back of the cable tray. Supporting structure, bracket or fixing material shall not have a sharp edge or abrasive effect on cables.

BMS/13.01.22. Conduit

BMS/13.01.23. Cable and Wire Colours

All single-phase wires and cables shall be colour coded, i.e. Red, Blue and Yellow colours. The earthing cable shall be Green and Neutral shall be Black.

BMS/ 14.00 Earthing & Bonding

BMS/14.01.1. General

This section covers the earthing system Criteria requirements for AC power system except for the traction power system.

Earthing of electrical systems and electrical equipment shall be designed in accordance with the following codes:

BS 7430	Code of Practice for Earthing
BS 7671	Wiring Regulations for Electrical Installations for Buildings
ANS/IEEE 80 1986	IEEE Guide for Safety in AC Substation Grounding Standard
IEEE 1100	Recommended Practice for Powering and Grouting of Sensitive

BMS/14.01.2. Electronic equipment

The Contractor shall provide the detailed design, manufacture, delivery and installation, functional testing and handover of a working earthing and bonding system. The extent and adequacy of the system must be established and a suitable testing method proposed to the Employer's Representative for consent as a sound and adequate procedure.

Earthing shall be carried out in accordance with the highest internationally accepted standards to allow safety equipment to operate properly and to maintain touch voltages to below 50V in the event of a short circuit in any part of the system.

Earthing shall be designed to ensure the following:

- Compliance with regulations
- Safety of persons. In particular passengers and staff shall be protected from the possibility of high potential to structural earth potentials and carrying the fault current to the Earth
- Correct operation of breakers and tripping devices and limitation of damage to plant, equipment or system failure
- Protection against interference
- Equipotential bonds to ensure touch voltages (between conducting components accessible to persons) during a fault condition do not exceed 50V.
- Avoid electrolytic corrosion of metal parts & structural elements.

BMS/14.01.3. Earth

Earthing and bonding cables shall be of copper with green/white oversheath.

The metallic sheaths and the armouring of all LV power cables shall be solidly earthed at both ends to the main earth system.

The frames and enclosures of all AC switchboards, Control Panels etc., shall be earthed directly to the main earth system.

BMS/ 15.00 Verification, Testing and Commissioning

BMS/15.01.1. General

The Contractor shall provide and perform all forms of test procedures applicable to the various systems and shall conduct factory, site installation and acceptance tests. The test procedure & schedule must be laid down by the Contractor in accordance with the governing standards and submit in advance to the Employer's representative. The procedure shall cover a trial run of at least 8 hours including critical conditions in addition to the tests mentioned in the specifications.

The commissioning activity shall include a period of test running followed by staff training.

All test results and compliance with acceptance criterion shall be recorded in suitable batches and preserved for handover to JMRC at the time of Hand Over.

The tests shall be specified to confirm the design life of various equipments, sub-assemblies and components. The design shall match the specified life. The test procedures shall be submitted for consent for each equipment.

~~BMS/15.01.2. Fire Alarms and Detectors~~

~~The fire detection and alarm system shall be tested in accordance with the approved testing procedures document. Each component and assembly shall be type tested and functionally tested before installation, and the entire system functionally tested for correct operation including all related equipment and interfaces with other System-wide Contractors' equipment.~~

BMS/15.01.3. Electrical Works

All cables, circuits, switch gear, UPS, DG set and components shall be fully tested for electrical integrity, safety and operation, and certified as such before commissioning.

All electrical circuits and equipment are to be fully commissioned after testing.

The Employer's Representative shall be advised at least two weeks prior to any testing or commissioning and will advise whether he is to be present some or all of the time to witness tests. Whether the Employer's Representative is present or not copies of test results shall be submitted to him within two weeks of successful tests being carried out.

BMS/15.01.4. Mechanical Works

The tests shall be specified to confirm the design life of various components / sub-assemblies / equipments. The design life shall match the specified life. The test procedures shall be submitted for consent of Employer’s representative for each equipment.

The contractor shall carry out testing of all ECS equipments separately for (I) air conditioning system (ii) ventilation system and (iii) smoke extraction system to establish proper functioning of individual equipment as well as the systems individually. The final testing should be carried out with all system in working as would be under normal conditions and then simulating the emergency conditions to establish the system-wide ability to manage such conditions. Such testing procedures to be submitted in all details.

BMS/15.01.5. Compressed Air System

The compressed air system shall be tested in accordance with the approved testing procedures document. Each component and assembly shall be type tested and functionally tested before installation, and the entire system functionally tested for pressures, and correct operation including all related equipment and interfaces with other equipment.

BMS/15.01.6. Earthing and Lightning Protection

The earthing protection system shall be tested in accordance with the approved testing procedures and document **by the Main earthing vendor**. Each component shall be type tested, each separate earth position and the entire system tested for correct low impedance.

General Requirements

The Contractor shall put in place a full testing regime to demonstrate that all the requirements of the Specification are met.

All the tests shall be carried out by the Contractor. The Employer's Representative reserves the right to carry out any additional tests he considers necessary to satisfy himself that the System meets the requirements of the Specification.

The Contractor shall support the Employer's Representative's additional tests as necessary. The Contractor's support shall include, but not be limited to:

- Provision of test equipment;
- Attendance of competent staff; and provision of test procedures.
- The Contractor shall submit a Testing and Commissioning program for the Employer's Representative's review within 6 months from the Date for Commencement of the Works.
- The Contractor shall provide details of the testing activities as specified in the Specification in the Testing and Commissioning program

Tests on Completion

BMS/15.01.7. General

On completion of the testing regime given in the Employer's Requirements - Manufacturing, Installation and Testing, it shall be the Contractor's responsibility to restore the TVS/ECS PLC Control System to full operational use following SAT.

During SAT, all interfaces with external systems to the TVS/ECS PLC System shall be tested.

Tests on completion shall constitute the necessary tests to demonstrate that the System meets the performance requirements of the Specification.

The plan and methodology for each test shall be developed by the Contractor and reviewed by the Employer's Representative no less than 120 days before the start of the test.

BMS/15.01.8. Test Logs

All tests including failures occurring during the Tests on Completion shall be recorded in a test log.

The Contractor shall maintain and analyse test logs on a daily basis, and summarise them on a weekly basis, to provide the following information:

- Total accumulated operating time per equipment type;
- Total accumulated failures of the system per equipment type with details of each failure; and
- Total accumulated repair and restore time for the failures of the system.

BMS/15.01.9. Pre-Revenue Operations

Certification shall be provided by the Contractor that the system is safe for passenger service prior to the commencement of the pre-revenue operations.

A plan for performance and functional tests and demonstrations to be performed during pre-revenue operations shall be submitted to the Employer’s Representative for review at least 120 days prior to the commencement of Pre-Revenue Operations.

A performance demonstration plan shall be submitted for review by the Employer’s Representative at least 120 days prior to commencement of the DLP.

BMS/ 16.00 Operation & Maintenance Support

BMS/16.01.1. General

The Contractor shall ensure that the design of the software and hardware of the TVS/ECS PLC Control Systems is supportable throughout the service life of the System to address, as a minimum, the following:

- Design errors in the System;
- Operational changes;
- Environmental changes; and
- Changes in infrastructure.

During the Defects Liability Period maintenance will be conducted by the Employer with the support of the Contractor.

The Contractor shall ensure that in order to support the Employer during the DLP, personnel are available with the relevant skills and level of competence.

The Contractor shall immediately inform the Employer upon it becoming apparent that the quality or supply of materials and components is or is likely to be affected, and without delay submit to the Employer's Representative for review its proposals for alternative sources of supply.

Maintenance during Defects Liability Period

BMS/16.01.2. Competency of Personnel

During the DLP the Contractor shall support the Authority with sufficient trained and competent personnel.

Such persons shall have their generic competence established and must demonstrate their specific competence and knowledge in the particular systems, environment and procedures.

The Contractor shall provide evidence of specific competence and knowledge, which shall include:

- Assessment and certified training in particular software applications and operations;
- Recording of competence and work in the license holders logbook; and
- Receiving or in receipt of sufficient and current exposure to the area of work that the holder is licensed for

Routine spot checks on licensing may be carried out from time to time by the Employer's Representative's qualified personnel on the proficiency of the Contractor's staff.

BMS/16.01.3. Defects Liability Management Plan

As part of the Defects Liability Management Plan, the Contractor shall detail the management and organisation to be provided during the DLP.

BMS/16.01.4. Discrepancies between Installation and Design Records

Should the Contractor discover inconsistencies between the maintenance drawings and documentation and the installed equipment, the Contractor shall correct all such errors within two weeks.

Support Documentation

BMS/16.01.5. Routine and Corrective Maintenance Procedures

Routine and corrective maintenance procedures shall be supplied for all equipment. The format shall be as follows:

- Uniform format and layout irrespective of equipment supplier;
- Colour coding for each activity;
- Cross referenced to the Operation and Maintenance Manuals; and
- Document control information.

The procedures shall be submitted for review by the Employer’s Representative; the following shall be included as a minimum:

- Frequency of maintenance;
- Type of maintenance;
- The equipment identification;
- Safety precautions to be observed;
- Step by step guide to the maintenance required; and
- Explanatory diagrams.

BMS/ 17.00 Spare Parts, Special Tools & Test Equipment

BMS/17.01.1. General

The Contractor shall provide spare parts for the Defects Liability Period in accordance with the requirements of the Employer's Requirements – Manufacture, Installation and Testing. All spare parts in which the Contractor has been authorised to provide through a written instruction by the Employer's Representative shall be provided 6 weeks before commencement of revenue service.

BMS/17.01.2. Spares List

The Contractor shall submit to the Employer's Representative a list of spares required for the life of the System.

The Contractor shall base the spares calculations on the reliability and availability data and the criticality of the equipment.

The Contractor shall submit to the Employer's Representative for review the calculations and spares list.

The list shall be grouped by subsystem, test equipment and special tools as applicable for stocking identification.

The list shall have detailed description with drawing references and correlation with the maintenance manuals.

BMS/17.01.3. Second Sourcing

The Contractor shall identify principal and second-source suppliers that can supply the systems and sub-system spares listed.

The Contractor shall ensure that second-source supplier information is maintained up to date throughout the service life of the System.

The Contractor shall make the second-source supplier information available to the Employer's Representative at the time of submission of the final design.

BMS/17.01.4. Long Lead Times

The Contractor shall identify the lead times for all spare parts. Parts with long lead times shall be identified as such to the Employer's Representative in the spares list.

BMS/17.01.5. Routine Change

In the event that any item of the supply requires to be routinely changed or calibrated, regardless of whether it appears in the spares list or not, it shall be identified to the Employer's Representative together with the routine change interval.

BMS/17.01.6. Shelf Life

In the event that any of the spares identified have a particular shelf life or storage requirement, this shall be made known to the Employer's Representative with the submission of the spares list, including the necessary action for disposal or storage.

BMS/17.01.7. Identification and Configuration Control

All spare equipment identified on the spares list, shall conform to Identification and Configuration Control requirements of the Employer's Requirements.

BMS/17.01.8. Testing of Spares

The Contractor shall ensure that all spares are correctly calibrated, tested and labelled prior to their delivery. Test certificates for each equipment shall be submitted to the Employer's Representative.

BMS/17.01.9. Tools and Test Equipment

The Contractor shall provide the necessary tools and test equipment to meet the testing, commissioning and maintenance requirements of the Contract.

The Contractor shall submit a schedule of all tools and equipment with details of calibration and supplier.

BMS/ 18.00 Training

BMS/18.01.1. General

Training shall be provided for Employer's engineers and staff such that the TVS PLC Control Systems can be operated and maintained in accordance with the Manufacturer's requirements.

The Contractor shall submit for review by the Employer's Representative a training plan 180 days prior to the first testing and commissioning activity.

BMS/18.01.2. Scope Of Training

The training shall include both normal and abnormal operations. At the discretion of JMRC training will be provided in the following categories:

Operations staff will include as a minimum:-

- Duty chief controller;
- Depot and station controllers;
- Engineering coordinator;
- Communications coordinator;
- Operations planners and scheduler; and
- Employer's Training Instructors and trainers.

Engineering staff shall include as a minimum:-

- Maintenance staff;
- Fault report centre staff;
- Design staff; and
- Employer's Training Instructors and trainers.

Management staff shall include as a minimum:-

- Supervisors;
- Line managers;
- Section managers; and
- Department managers.

Normal and Abnormal Operation

The Contractor shall train the Employer's engineers and staff in the normal day to day operation of the BMS for stand-alone and integrated operation and maintenance of all control, monitoring, and supervision functionality of the Tunnel Ventilation Systems and Low Voltage Power & Distribution, Fire Alarm System, Hydraulic System (Seepage, Sewage, Bore Well Pumps etc **for control, monitoring, and supervision at the Operational Control Centre (OCC).**

BMS/18.01.3. System Design and Configuration

The Contractor shall provide training to the Employer's engineers and staff in the design and configuration of the System. This training shall include:

- Systems overview;
- Systems configuration and data preparation; and
- Principles of operation.

BMS/18.01.4. Maintenance Training

Training shall be provided to the Employer's engineers and staff to undertake maintenance of the System provided following substantial completion of the Works. This training shall include:

- Principles of operation;
- Preventative and corrective maintenance tasks and procedures;
- Fault repair to the lowest level replaceable unit;
- Use of test equipment, diagnostic and maintenance aids; and
- Software maintenance including database structure, generation, modification and system software organisation.

In conjunction with the 3VAC Contractor the Contractor shall conduct at least 2 courses on the maintenance aspects of the Tunnel Ventilation System. The courses will be attended by about 20 Employer's staff.

BMS/18.01.5. Training Format

The Contractor shall comply with relevant clause of Employer's Requirements - Manufacturing, Installation and Testing.

BMS/ 19.00 Contract Documentation

BMS/19.01.1. General Requirements

This section defines how submissions, including Design Documents and other material submitted for review by the Employer's Representative, shall be presented and controlled.

BMS/19.01.2. Submission Control

The Contractor shall submit a Submissions Programme in accordance with the Employer's Requirements. In addition, the Submissions Programme shall:

- identify all design, manufacturing, testing, operations and maintenance contract deliverables, required by the Specification; and
- assign reference numbers to all submissions.

All documentation shall be submitted to the format contained in the Employer's Requirements.

Textual submittals, including reports, specifications, and calculations, shall also be submitted in electronic form, wherever feasible.

All 'As built' final documentation, including drawings and support documentation, shall be electronically stored on CD ROM media. The Contractor shall, not less than 90 days prior to the substantial completion of the last Section of each Corridor, submit a first draft of the documentation CD to the Employer's Representative. A final version shall be submitted at the time when the Contractor applies to the Employer's Representative for a Substantial Completion Certificate. Any updates due to design changes during testing or revenue service shall be at the Contractor's expense.

The Standard CD ROM format shall be as defined in ISO 9660. The Contractor shall demonstrate that drawings reproduced from the CD-ROM are legible. Legibility will be determined by being able to distinguish all dimensions, dimension lines, outlines and dashlines without use of supplementary viewing aids.

The CD ROM format shall be consistent with the CAD system specified by the Authority at the time of delivery.

BMS/19.01.3. Contractor's Responsibilities

In addition to the requirements of the Employer's Requirements, the Contractor shall ensure that the requirements contained herein are carried out.

The Contractor shall maintain a complete up-to-date, organised file of all past and current submissions including an index and locating system, which identifies the status of each submission.

The index shall be available for the Employer's Representative's review, and shall be used to:

- Assign sequential numbers to each contract deliverable; and

- Assign new deliverable numbers to all resubmissions and cross-reference to previous submissions.

The Contractor shall provide supplemental information with each submission, in sufficient detail to explain completely the equipment described and their intended manner of use.

BMS/19.01.4. Material Contract Deliverables

Materials deliverables shall be identified by a clear and durable identification plate, which shall include the following information:

- Issue and revision status and date;
- Contract title and number;
- The names of the Contractor, subcontractor, supplier or manufacturer;
- Identification of product by either description, model number, type number or serial number; and
- Subject identification by Contract Drawing, Design Drawing or Specification reference.

BMS/19.01.5. Supplemental Modification Deliverables

Changes in submissions previously reviewed without objection will not be permitted unless those changes are resubmitted in the same manner as the original deliverable and reviewed by the Employer's Representative.

BMS/ 20.00 APPENDIX B – INPUT/OUTPUT INTERFACES

The following schedule of Input/Output Interfaces is provided for guidance purposes only. It is the responsibility of the contractor to interpret the entire requirements of the specification and to provide Input/Output interfaces as required which may be described separately throughout this specification.

	Plant Room or Local PLC control (PLC)		**Station Control Room display**		**OCC/SCADA**
Functions	**Metering**	**Operation**	**Status**	**Alarm**	**Remote data**
1. Pumps					
			Control room display for items A,B,C&D		
A. Raw water pumps 1+1 for each water treatment plant	Water treatment plant ON	Start pump	WT plant 1/2/3 ON/OFF/ Back wash		
	Liquid level in the filter water tank low	Log at PLC		Warning, goes off when tank is full	
	Manual bypass switch local or remote				
	Pump running	-	Pump 1/2 ON (OFF)	-	-
	Pump failure	Start Standby		Standby pump fail warning	D(1) warning
	Standby pump fail	-		Both pump fail Alarm	D(1) Alarm
	Water level in the Filter water tank	If full, stop pumping Log at PLC	-	-	-
	Pumping completed	Alternating Pumps	-	-	-
	Hours of operation	Log at PLC	-	Not run for more than a week (Alarm)	D(1) warning

	Plant Room or Local PLC control (PLC)		Station Control Room display		OCC/SCADA
Functions	**Metering**	**Operation**	**Status**	**Alarm**	**Remote data**
	Voltage	Log at PLC	-	No volt Warning	-
	Current	Log at PLC	-	-	-
	Energy (power factor)	Log at PLC	-	-	-
B. Filter water pumps for stations	Manual bypass switch local or remote	Start pump		Warning, goes off when tank is full & OCC warning is OFF	D(1) warning
	Pump running	-	Pump 1/2/3 ON (OFF)	-	-
	Pump failure	Start standby		Standby pump fail warning	
	Standby pump fail	Start standby		Two pump fail warning	D(1) warning
	Second standby pump fail	Start standby		Third pump fail Alarm	D(1) Alarm
	Water level in the collecting tank at the depot	If full, stop pumping Log at PLC	-	-	-
	Pumping completed	Alternating pumps	-	-	-
	Hours of operation	Log at PLC	-	Not run for more than a week (Alarm)	D(1) warning
	Voltage	Log at PLC	-	No volt Warning	-
	Current	Log at PLC	-	-	-
	Energy (power factor)	Log at PLC	-	-	-

	Plant Room or Local PLC control (PLC)		Station Control Room display		OCC/SCADA
Functions	**Metering**	**Operation**	**Status**	**Alarm**	**Remote data**
C. Sedim-entation sump pump (1+1)	Timer, two hours operation for every eight hours	Start pump			
	Manual bypass switch local or remote				
	Pump running	-	Pump1/2 ON (OFF)	-	-
	Pump failure	Start standby		Main pump fail warning	-
	Standby pump fail	-		Both pump fail Alarm	D(1) warning
	Water level in the sewage tank	If empty stop pumping Log at PLC		-	-
	Pumping completed	Alternating pumps	-	-	-
	Hours of operation	Log at PLC	-	Not run for more than a week (Alarm)	D(1) warning
	Voltage	Log at PLC	-	No volt Warning	-
	Current	Log at PLC	-	-	-
	Energy (power factor)	Log at PLC	-	-	-
D. Borewell pumps at station	Liquid level in the collecting tank low & water mains failure	Start pump		Warning, goes OFF when collecting tank full	D(1) warning

	Plant Room or Local PLC control (PLC)		Station Control Room display		OCC/SCADA
Functions	Metering	Operation	Status	Alarm	Remote data
(1+1)	Manual bypass switch local or remote	log at PLC		-	-
	Liquid level in the fire tank low		Fire tank full	Warning, goes OFF when fire tank full	D(1) warning
	Pump running	-	Pump ON (OFF)	-	-
	Pump failure	-		Standby pump fail warning	D(1) warning
	Water level in the collecting tank	If full, stop pumping Log at PLC	-	-	-
	Pumping completed	Alternating pumps	-	-	-
	Hours of operation	Log at PLC	-	Not run for more than a week (Alarm)	D(1) warning
	Voltage	Log at PLC	-	No volt Warning	-
	Current	Log at PLC	-	-	-
	Energy (power factor)	Log at PLC	-	-	-
E. Sewage pumps	Liquid level in the sewage tank high	Start pump	-	Warning, goes OFF when tank is empty	-
(1+1)	Manual bypass switch local or remote				
	Pump running	-	Pump1/2 ON	-	-
	Pump failure	Start standby		Main pump fail warning	-

	Plant Room or Local PLC control (PLC)		Station Control Room display		OCC/SCADA
Functions	**Metering**	**Operation**	**Status**	**Alarm**	**Remote data**
	Standby pump fail	-	(OFF)	Both pump fail Alarm	D(1) warning
	Water level in the sewage tank	If empty stop pumping Log at PLC		-	-
	Pumping completed	Alternating pumps	-	-	-
	Hours of operation	Log at PLC	-	Not run for more than a week (Alarm)	D(1) warning
	Voltage	Log at PLC	-	No volt Warning	-
	Current	Log at PLC	-	-	-
	Energy (power factor)	Log at PLC	-	-	-
F. Seepage pumps	Liquid level in the seepage tank very high	Start all the three pumps	-	Warning, goes OFF when tank is empty	D(1) warning
(1+1+1)	Liquid level in the seepage tank high	Start pump	-		-
	Manual bypass switch local or remote				-
	Pump/s running	-	Pump 1/2 /3 ON (OFF)	-	-
	Pump failure	Start standby		First pump fail warning	D(1) warning
	Standby pump fail	Start second standby		Second pump fail Alarm	

	Plant Room or Local PLC control (PLC)		Station Control Room display		OCC/SCADA
Functions	**Metering**	**Operation**	**Status**	**Alarm**	**Remote data**
	Second Standby pump fail	-		Third pump fail Alarm	D(1) Alarm
	Water level in the sewage tank	If empty stop pumping Log at PLC		-	-
	Pumping completed	Alternating pumps	-	-	-
	Hours of operation	Log at PLC	-	Not run for more than a week (Alarm)	D(1) warning
	Voltage	Log at PLC	-	No volt Warning	-
	Current	Log at PLC	-	-	-
	Energy (power factor)	Log at PLC	-	-	-
G. Fire fighting pump	Operation of fire hose	Start the pump	-	Warning	D(1) warning
(1+1)	Hydrant pressure fall (major)		-		
	Pump running	-	Pump1/2 ON (OFF)	-	-
	Pump failure	Start standby		First pump fail warning	D(1) warning
	Standby pump fail	-		Second pump fail Alarm	D(1) Alarm
	Water level in the fire tank	Log at PLC		Alarm if low	D(1) warning
	Hours of operation	Log at PLC	-	Not run for more than a week (Alarm)	D(1) warning

	Plant Room or Local PLC control (PLC)		Station Control Room display		OCC/SCADA
Functions	**Metering**	**Operation**	**Status**	**Alarm**	**Remote data**
H. Jockey pump	Operation of fire hose	Start the pump	-	-	-
(for fire)	Hydrant pressure fall (minor)		-	-	-
	Manual bypass local or remote	Start the pump		-	-
	Hydrant Pressure Fall (minor)				
	Manual by-pass local or remote				
	Pump running	-	ON (OFF)	-	-
	Pump failed	-		Alarm	D(1) warning
	Hydrant pressure	Stop pump if adequate Log at PLC	-	Warning if low pressure	-
	Hours of operation	Log at PLC	-	Not run for more than a week (Alarm)	D(1) warning
	Voltage	Log at PLC	-	No volt warning	-
	Current	Log at PLC	-	-	-
	Energy (power factor)	Log at PLC	-	-	-
2.Emergency lighting					
A. DG set	Incoming HT supply to ASS 1&2 transformers OFF	Bus couplers OFF, start DG set, load breaker ON	Starting the DG set	Warning, Supply failed	D(1) warning
	Start command from control panel	start DG set, load		_	-

	Plant Room or Local PLC control (PLC)		Station Control Room display		OCC/SCADA
Functions	**Metering**	**Operation**	**Status**	**Alarm**	**Remote data**
	Start command from Local or remote	breaker OFF		-	-
	DG set running		ON(OFF)		
	Incoming HT supply to ASS transformers ON	DG set OFF Bus couplers ON		-	-
	DG set failed to start or tripped			Alarm	D(1) Alarm
	Hours of operation	Log at PLC	-	Not run for more than a week (Alarm)	D(1) warning
	Starter battery voltage	If low Log at PLC		Warning, Maintenance required	D(1) warning
	Lube oil level	If low Log at PLC			
	Fuel oil level	If low Log at PLC			
	Radiator water level	If low Log at PLC			
	Output voltage	Log at PLC	Within range, indicate on load	Alarm, if out of range	D(1) Out of range alarm
	Output frequency	Log at PLC			
B UPS	Input voltage low		-	Supply failed	D(1) warning if supply fails for more than 5 minutes
	Input frequency low		-		

	Plant Room or Local PLC control (PLC)		Station Control Room display		OCC/SCADA
Functions	**Metering**	**Operation**	**Status**	**Alarm**	**Remote data**
	Battery failed	Start second battery	ON (OFF)	Warning, Maintenance required	
	Charger failed	Start second charger			
	Inverter failed	Start second inverter			
	Control module one failed	-			
	Control module two failed	-			
	Second battery failed	-		Alarm, immediate attention to the UPS	D(1) Alarm
	Second charger failed	-			
	Second inverter failed	-			
	Hours of operation	Log at PLC	-	-	-
	Out put bus voltage low		-	Alarm, manual fault attention	-
	UPS failed			Alarm	D(1) Alarm
C. Tunnel circuits	Voltage	-	ON(OFF)	No volt Alarm	D(1) Alarm
A,B,C or D	Current	If less than 80% of nominal value in any circuit		Lamp replacements due	
	Hours of operation	Log at PLC	-	-	-

	Plant Room or Local PLC control (PLC)		Station Control Room display		OCC/SCADA
Functions	**Metering**	**Operation**	**Status**	**Alarm**	**Remote data**
D. Platform emergency lights	Voltage	-	ON(OFF)	No volt Alarm	D(1) Alarm
E. A,B,C or D	Current	If less than 80% of nominal value in any circuit		Lamp replacements due	
	Hours of operation	Log at PLC	-	-	-
F. Control supply	Voltage	-	ON(OFF)	No volt Alarm	D(1) Alarm
	Hours of operation	Log at PLC	-	-	-
G. Entry/exit/ lighting	Voltage	-	ON(OFF)	No volt Alarm	D(1) Alarm
	Current	If less than 80% of nominal value in any circuit		Lamp replacements due	
	Hours of operation	Log at PLC	-	-	-
3. Fire Detection and Alarm System					
All Zones Public Areas	Alarm situation	Signal at FAP	-	WARNING	D (1) warning
All Zones Non Public Areas	Alarm situation	Signal at FAP	-	WARNING	D (1) warning
ALL Zones Electrical	Alarm situation	Release Gas Agent	-	WARNING	D (1) warning

	Plant Room or Local PLC control (PLC)		Station Control Room display		OCC/SCADA
Functions	**Metering**	**Operation**	**Status**	**Alarm**	**Remote data**
Installations					
ALL Zones non-hazardous areas	Alarm situation	Signal at FAP	-	WARNING	D (1) warning
FAP	System fault	Fault indication	ON	WARNING	D (1) warning
	External fault	Fault indication	ON	WARNING	D (1) warning
	Processor fault	Fault indication	ON	WARNING	D (1) warning
	Device fault/Device isolated	Fault indication		WARNING at fixed interval	D (1) warning
	Voltage	Log at LDC		No volt warning	-
	Maintenance Alarm	Device fault			-
Hydrant	Low Pressure	Start Pump	ON	WARNING	

END OF APPENDIX B

BMS/ 21.00 APPENDIX C – OCC INTERFACES

The following schedule of OCC Interfaces is provided for guidance purposes only. It is the responsibility of the contractor to interpret the entire requirements of the specification and to provide Input/Output interfaces as required which may be described separately throughout this specification.

	Building Services System (BMS)	**Signal 1**	**Signal 2**
	LV ELECTRICAL SYSTEM		
1.	**LOW VOLTAGE POWER SUPPLIES A & B**		
	Main Incoming Supply from ACC's	Healthy	Fail
	Amps	Current	
	Volts	Volts	
	Kilowatts	Kilowatts	
	VA	Volt Ampere	
	Hz	Frequency	
	PF	Power actor	
	VAR	Volt Ampere Reactive	
	Kwh	Kilowatt Hour	
	ACB's		
	Accessibility of Control from Station	Remote	Local
	Status	Open	Closed
	Control Command	Open	Close
	Fault	Trip	Cause of Tripping
	Protection Function	Read Setting	Set Parameters
	MCCB		
	Positive Status	Open	Closed
	Fault	Trip	Cause of Tripping
	Amps	Current	
	Protection Function	Read Setting	Set Parameters
	Dual Feed Auto Transfer Switches – ALL	Healthy	Fail
2.	**UNINTERRUPTIBLE POWER SUPPLIES**		
	UPS Power Supply at Equipment	Healthy	Fail
3.	**UPS EQUIPMENT**		
	Low Input Voltage Alarm	Alarm	
	Low Input Freq Alarm	Alarm	
	Second Battery Fail	Alarm	
	Second Charger Fail	Alarm	
	Second Inverter Fail	Alarm	
	Not in operation 1 week	Alarm	
	UPS Fail	Alarm	
4.	**DIESEL GENERATOR SETS**		
	Incomer HT to ASS 1 & 2 Fail	Alarm	
	DG Fail to Start	Alarm	
	DG Not run for 1 week	Alarm	
	DG Starter Battery Low Voltage	Alarm	

	Building Services System (BMS)	Signal 1	Signal 2
	DG Lube Oil Low	Alarm	
	DG Fuel Low Level	Alarm	
	Radiator Water Low	Alarm	
	DG Output Voltage out of limit	Alarm	
	DG Output Frequency out of limit	Alarm	
5.	**EMERGENCY LIGHTING**		
	Emergency Lighting (all sub circuits) No voltage	Alarm	
	Tunnel Lighting No voltage	Alarm	
	Control Supply (all equipment) No voltage	Alarm	
	Entry/Exit Lighting (all sub circuits) No voltage	Alarm	
6.	**EMERGENCY SIGNAGE STATUS**		
	ALL sub circuits – no voltage	Alarm	
	FIRE ALARM DETECTION & SUPPRESSION		
7.	**FIRE ALARM AND DETECTION SYSTEM**		
	FAS -Power Healthy	Healthy	Fail
	FAS -Panel System Fault	Alarm	
	FAS -Panel External Fault	Alarm	
	FAS -Panel Processor Fault	Alarm	
	FAS -Zone Alarm - ALL ZONES	Alarm	
	FAS -Zone Fault - ALL ZONES	Alarm	
8.	**FIRE FIGHTING PUMP**		
	Main Fire Pump Running	On	Off
	Main Fire Pump Fail	Tripped	
	Main Fire Pump not run one week	Alarm	
	Main Standby Fire Pump Fail	Alarm	
9.	**JOCKEY PUMP FOR HYDRANT SYSTEM**		
	Jockey Pump Running	Alarm	
	Jockey Pump not run one week	Alarm	
9.	**ESCALATOR SPRINKLER PROTECTION**		
	Power Healthy	Healthy	Fail
	Panel Fault	Alarm	
	Zone Alarm - ALL ZONES	Alarm	
	Zone Fail - ALL ZONES	Alarm	
10.	**DRY AGENT SYSTEMS (ALL)**		
	Power Healthy	Healthy	Fail
	Panel Fault	Alarm	
	Zone Alarm - ALL ZONES	Alarm	
	Zone Fail - ALL ZONES	Alarm	
	HYDRAULIC SYSTEMS		

	Building Services System (BMS)	Signal 1	Signal 2
12.	**SEEPAGE PUMPS**		
	Liquid level in sump high	Alarm	
	First Pump Fail	Alarm	
	Second Pump Fail	Alarm	
	Third Pump Fail	Alarm	
	Standby Pump not run 1 week	Alarm	
13.	**SEWAGE PUMPS**		
	Liquid level in sewage tank high	Alarm	
	Main Pump Fail	Alarm	
	Standby Pump Fail	Alarm	
	Standby Pump not run 1 week	Alarm	
14.	**WATER STORAGE TANK**		
	Low Level Alarm	Alarm	
15.	**STAND BY BOREWELL PUMPS AT STATIONS**		
	Liquid level in the collecting tank low & water mains failure	Alarm	
	Liquid level in the fire tank low	Alarm	
	Pumps Fail	Alarm	
	Standby Pump not run 1 week	Alarm	
16.	**DOMESTIC POTABLE WATER**		
	Pumps Fail	Alarm	
	Standby Pump Fail	Alarm	
	Standby Pump not run 1 week	Alarm	
	ECS HVAC SYSTEMS		
17.	**SUPPLY AIR FANS**		
	Accessibility of Control from Station	Remote	Local
	Positive Status	On	Off
	Control Command	Running	Stopped
	Fault	Tripped	
	Low Airflow - Normal/Alarm	Alarm	
	Motor Current Low/High	Alarm	
	Emergency Stop Button	Alarm	
18.	**EXHAUST AIR FANS**		
	Accessibility of Control from Station	Remote	Local
	Positive Status	On	Off
	Control Command	Running	Stopped
	Fault	Tripped	
	Low Airflow - Normal/Alarm	Alarm	
	Emergency Stop Button	Alarm	
	Motor Current Low/High	Alarm	
19.	**STANDBY EXHAUST FANS**		
	Accessibility of Control from Station	Remote	Local

	Building Services System (BMS)	Signal 1	Signal 2
	Positive Status	On	Off
	Control Command	Running	Stopped
	Fault	Tripped	
	Low Airflow - Normal/Alarm	Alarm	
	Motor Current Low/High	Alarm	
	Emergency Stop Button	Alarm	
20.	**AIR HANDLING UNITS**		
	Accessibility of Control from Station	Remote	Local
	Positive Status	On	Off
	Control Command	Running	Stopped
	Fault	Tripped	
	Fan Airflow - Normal/Alarm	Alarm	
	Fan Motor Current Low/High	Alarm	
	Filter - Normal/Alarm	Alarm	
	Emergency Stop Button	Alarm	
21.	**MOT VOLUME CONTROL DAMPER**		
	Damper	Open	Closed
22.	**CHILLED WATER PUMPS**		
	Low Flow - Normal/Alarm	Alarm	
	Motor Current Low/High	Alarm	
	Pump not run one week	Alarm	
23.	**CONDENSOR WATER PUMPS**		
	Low Flow - Normal/Alarm	Alarm	
	Motor Current Low/High	Alarm	
	Pump not run one week	Alarm	
24.	**COOLING TOWER**		
	Motor Current Low/High	Alarm	
25.	**CHILLERS**	Alarm	
	Chiller Outlet Temp High Alarm	Alarm	
	Motor Current Low/High	Alarm	
	Common Chiller Temp High Alarm	Alarm	
	Common Condensor Temp High Alarm	Alarm	
	Condensor Temp High Alarm	Alarm	
	Chiller Fail	Alarm	
	Chiller Common Alarm	Alarm	
	Chiller Temperatures	Value	
26.	**REFRIGERANT MONITORING**	Alarm	
27.	**CHEMICAL TREATMENT**	Alarm	
28.	**STATION TEMPERATURES**	Value	
29.	**STATION HUMIDITY**	Value	
30.	**STAIR PRESSURISATION FANS**		

	Building Services System (BMS)	Signal 1	Signal 2
	Accessibility of Control from Station	Remote	Local
	Positive Status	On	Off
	Control Command	Running	Stopped
	Fault	Tripped	
	Emergency Stop Button	Alarm	

31.	**MODE CONTROL (ECS) (Subject to Design)**		
	Mode Command from OCC	Command	
	Mode Confirm Receipt to OCC	Feedback	
	Mode Start Confirm from OCC	Command	
	Mode Accepted	Feedback	
	Mode In Progress	Feedback	
	Mode Successful	Feedback	
	Mode Fail	Alarm	
	Sub Mode Command from OCC	Command	
	Sub Mode Confirm Receipt to OCC	Feedback	
	Sub Mode Start Confirm from OCC	Command	
	Sub Mode Accepted	Feedback	
	Sub Mode In Progress	Feedback	
	Sub Mode Successful	Feedback	
	Sub Mode Fail	Alarm	
	Motor Current Low/High Alarm		
32.	**MOTORISED FIRE DAMPERS**	Open	Closed
	TUNNEL VENTILATION SYSTEMS		
33.	**MOTOR CONTROL CENTRES**		
	Amps	Current	
	Volts	Volts	
	Kilowatts	Kilowatts	
34.	**TUNNEL FANS (ALL TEF, TVF)**		
	Accessibility of Control from Station	Remote	Local
	Positive Status	On	Off
	Control Command	Running	Stopped
	Fault	Tripped	
	Emergency Stop Button	Alarm	
	Forward Airflow Low Alarm	Alarm	
	Reverse Airflow Low Alarm	Alarm	
	Airflow Status	Forward	Reverse
	Motor Overload	Alarm	
	Vibration Switch	Alarm	
	Motor Current Low/High Alarm	Alarm	
	Fan Fail	Alarm	
35.	**TUNNEL VENT DRAUGHT RELIEF DAMPERS**		
	Damper	Open	Closed
	Damper Command Mismatch	Alarm	

36.	**TUNNEL VENT FAN DAMPERS**		
	Damper	Open	Closed
37.	**TUNNEL VENT TRACKWAY DAMPERS**		
	Damper	Open	Closed
	Damper Command Mismatch	Alarm	

40.	**MODE CONTROL (TVS) (Subject to Design)**		
	Mode Command from OCC	Command	
	Mode Confirm Receipt to OCC	Feedback	
	Mode Start Confirm from OCC	Command	
	Mode Accepted	Feedback	
	Mode In Progress	Feedback	
	Mode Successful	Feedback	
	Mode Fail	Alarm	
	Sub Mode Command from OCC	Command	
	Sub Mode Confirm Receipt to OCC	Feedback	
	Sub Mode Start Confirm from OCC	Command	
	Sub Mode Accepted	Feedback	
	Sub Mode In Progress	Feedback	
	Sub Mode Successful	Feedback	
	Sub Mode Fail	Alarm	
	Control at OCC	Feedback	
	Control at SCR	Feedback	
	Control at VCP	Feedback	
	Control at LCP	Feedback	
	Control at FCP	Feedback	

END OF APPENDIX C

TVS SCADA SYSTEM (OCC)

TABLE OF CONTENTS

1. INTRODUCTION

1.1 General

1.1.1 This Document specifies the particular technical and performance requirements of the Supervisory Control and Data Acquisition (SCADA) System provided by TVS contractor at OCC.

1.2 OVERVIEW OF THE TVS SCADA SYSTEM

1.2.1 E&M equipment distributed throughout the underground corridors is to be monitored/ controlled during the normal as well as emergency operating conditions. The TVS SCADA shall also provide relevant data / information, which would enable maintenance staff to assess the need for unscheduled preventive maintenance based on degradation of normal operating parameters.

1.2.2 In addition, fault and failure warnings and alarms shall be monitored to provide the OCC staff with information about the capacity of these systems to cope with the traffic being carried.

1.2.3 The equipment to be monitored and / or controlled from the field by TVS SCADA in OCC. At stations in Underground section

- Fire Detection & Suppression system;
- LV station circuits (i.e. Lights, UPS, Diesel Generator);
- Pumps (Fire Main, Sprinklers, Drainage, Drinking Water, Sewage);
- Environmental Controls (ECS) Air Conditioning, Heat exhaust, Smoke Control;
- Tunnel Ventilation System (TVS) including mode setting for Fans & Dampers.

1.3 Operation Control Centre

1.3.1 The Operation Control Centre (OCC) are the heart of the system as far as dealing with normal and emergency operation of the JMRC system.

1.3.2 At the OCC, workstations are to be provided giving an effective means of display of fault and failure conditions to the Chief Controller (CC) and Assistant to the Chief Controller (ACC) in OCC. The CC will be provided with a simple list of current high level alarms and warnings, The ACC will receive the same list but in addition will acknowledge receipt of the indications and will be provided with details of the additional subsidiary alarms which are filtered out of the CC's list.

1.3.3 At the OCC, a workstation is to be provided giving effective means of monitoring the alarm detection from the electrical, fire, hydraulic and ECS systems, for individual stations and groups of stations by the Security Controller (SC).

1.3.4 At the OCC, a workstation is to be provided giving effective means of controlling the operation of TVS equipment for individual stations and groups of stations by the Auxiliary Systems Controller (AuxC). The Contractor shall incorporate necessary software on the decision making logic (mode tables) supplied by the TVS designer.

1.3.5 The central SCADA server shall maintain an historical database of all messages transmitted over the SCADA links and received from the Network management computers. The Contractor shall provide a means of accessing and processing that database.

1.3.6 All messages shall be time stamped at origin from a time source linked to the system master clock and the database listing shall be maintained in chronological order of the originating time stamps.

1.4 Training Facility

1.4.1 The Contractor shall supply training equipment and training course materials for SCADA operators and maintainers.

1.4.2 The initial training shall be undertaken at a suitable site to be provided by the Contractor

2 SCOPE OF THE WORKS

2.1 General

2.1.1 The specific requirements on the scope of the Works for the SCADA shall be as specified herein.

2.1.2 The Contractor shall design, supply, install test and commission a processor based **state-of-the-art** TVS Supervisory Control and Data Acquisition (SCADA) system for smooth operation, monitoring, control and logging of important features of the power systems on the underground corridors as detailed below.

2.1.3 In addition the Contractor shall supply spare parts, training for maintainers and operators, support for the Employer's maintenance staff and warranty of the equipment to ensure the ongoing functioning of the equipment after commissioning.

2.1.4 The Contractor shall undertake interface discussions with the contractors whose equipment is to be monitored by the TVS SCADA to agree the extent and configuration of both the physical and electrical interfaces to be provided. The Contractor shall assess the level of data being received from the monitored equipment to classify each datum as record, warning or alarm indications and shall process the data to be displayed based on this classification

2.2 Scope of Supply

2.2.1 The TVS SCADA System shall include, but not be limited to, the following :

(1) TVS SCADA central control and server equipment at OCC;

(2) switching equipment;

(3) VDU's/Workstation's/MMI's;

(4) RTU's at stations, ;

(4a) Communication link from interface cabinet at the equipment rooms at the stations, SCR/TER to RTU (as necessary) including its power supply.

(5) local and remote alarm interface to communication system supervisor

(6) all software required for the operation of the TVS SCADA ;

(7) testing and commissioning facilities;

(8) equipment cabinets, racks and cubicles;

(9) mounting brackets and installation materials;

(10) all equipment power supplies, cables, connectors, accessories, cabling
and earthing necessary for the works.

2.3 **Works excluded from this Contract**

2.3.1 The equipment to be monitored and controlled for other systems shall not be included as part of this contract. The arrangement for control and monitoring of equipment supplied by others up to the SCR and the integrated display other then the equipments supplied by TVS Contractor at SCR shall not be included as part of this contract.

3 **FUNCTIONAL REQUIREMENTS**

3.1 **General**

3.1.1 In addition to the design requirements as identified in Chapter 1 of this particular specifications, the TVS SCADA shall meet the technical system performance and equipment specification as specified herein.

3.1.2 The TVS SCADA shall be designed with fault tolerant system architecture to prevent common mode failure.

3.1.3 The software shall be designed to accommodate the ultimate, fully expanded capacity, without requiring any change to the hardware or firmware of the installed system and without affecting the overall operation or performance of the TVS SCADA

3.2 **Location**

3.2.1 The TVS SCADA system equipment is to be installed into various areas, viz. Station Equipment Rooms, Station Control Rooms, OCC Equipment Rooms, OCC Operations Theatre, Other OCC offices.

3.2.2 The equipment to which the TVS SCADA interfaces is distributed throughout the underground corridor of CS-QM line. The equipment and the related transducers shall be supplied, installed and maintained by the supplier of the equipment to be monitored.

3.2.3 The Physical Interface Locations are generally a set of terminals within an Interface Cabinet provided by others (generally the supplier of the equipment to be monitored). In some instances the terminals and cabinet may be the actual control equipment and control cabinet for the equipment being monitored. All cabling and wiring upto and including the Interfacing Cabinet (IC) shall be supplied and installed by the supplier of the equipment to be monitored. This shall also include all protection devices to be provided for the cables & the transducers.

3.2.4 Fire Detection & Suppression (FD&S) system.

The main Local Control Panel for the Fire Detection system (including indications for fire sprinklers and automatic extinguishers) will be located at the SCR and a repeater shall be provided at one of the main station entrances designated as the firemen's entrance. The interface between SCADA and fire detection & suppresion system shall be in the Interface Cabinet in the Station Control Room.
incorporated into this control cabinet.

3.2.5 LV station circuits.

The LV circuits will generally be controlled from LV panels in the station Auxiliary Sub-stations (ASS), one at each end of the station. An Interface Cubicle / switch will be provided in TER/SCR

3.2.6 Pumps.

3.2.6.1 Pumps incorporated into other larger systems, e.g. A/C chilled water circuits, will be monitored by the system equipment for the larger system to which the interface will be made.

3.2.6.2 Standalone pumps such as tank filling and emptying pumps will have local logic controls based on level switches and sequencing circuits to cycle pump duties between main and standby units.

3.2.6.3 The Interface Cabinets for stand-alone pump systems will be adjacent to or incorporated into the control cabinets for the local logic located within the pump equipment room.

3.2.7 ECS

3.2.7.1 The Interface Cabinet for the ECS will be installed adjacent to or incorporated into the ECS logic controller located within the ECS equipment room.

3.2.7.2 The ECS logic controller will also provide indications to and will receive controls from the combined ECS / TVS panel in the SCR.

3.2.8 Not Used.

3.2.9 TVS.

3.2.9.1 The Interface Cabinet for the TVS will be installed adjacent to or incorporated into the TVS local sequence controller located within the TVS equipment room at each end of the station.

3.2.9.2 The local sequence controller will also receive controls and provide indications to a Local Control panel in the TVS equipment room and also to the combined TVS / ECS panel in the SCR.

3.2.10 Fibre Optic Transmission System (FOTS)

3.2.10.1 The FOTS including Master Clock system will be controlled and monitored from the FOTS server in the OCC Telecommunication equipment room **(supplied by others).** In case of Clock Systems; the information will have to be retrieved through FOTS or via RTUs at stations and depots or through channel interfaces.

3.3 **Equipment**

3.3.1 Remote Terminal Units

3.3.1.1 Necessary Remote Terminal Units (RTUs) shall be installed to provide the most economic configuration based upon cost balances between RTU modularity and cabling costs, consistent with the performance requirements of this Specification.

3.3.1.2 RTUs shall be powered by a supply, which includes a back up to the main incoming power supply as part of the Power Supply System.

3.3.1.3 Communications between the RTUs interfacing to the field equipment and the TVSSCADA server in the OCC equipment room shall be over a duplicated communications network (based on the FOTS), which shall be provided on the main communications bearer, supplied under signalling contract. An electrical communications interface between the bearer transmission equipment and the RTUs shall be provided as part of each station N-P SCADA equipment.

3.3.1.3.1 In the event of a communications failure between a station and the central TVS SCADA server, the station TVS SCADA equipment provided under this contract, shall continue to function as an autonomous system, maintaining a local database and receiving and time stamping data from the monitored equipment. The monitoring and control functions, for the SCR provided by others (suppliers of

equipment to be monitored) shall not be under the scope of this contract.

3.3.2 Operations Control Centre Theatre

3.3.2.1 Within the OCC operations theatre, TVS SCADA displays shall be provided to allow the following functions for the nominated OCC personnel:

CC - Display real time list of high level equipment fault, fire and intruder alarms and warnings showing local acknowledgement and maintenance work status. Access historical list of all high level alarms and warnings showing time on, time off, time acknowledged etc..

ACC - Display list of high level and detail equipment fault alarms and warnings, require acknowledgement of alarms, allow inquiry to show detail behind high level alarms including local acknowledgement status, allow tagging of alarms to show work in progress / alarm bypass / maintenance call logged etc.. Access historical list of all high level alarms and warnings showing time on, time off, time acknowledged etc..

SC - Display real time fire and intruder alarms, require acknowledgement of alarms. Access historical list of fire and intruder alarms and warnings showing time on, time off, time acknowledged etc..

CSS - Display list of summary alarms, acknowledgement of alarms, allow inquiry to show detail of alarms for all systems covered under TVS SCADA. However no acknowledgement of alarms except for FOTS including Master Clock Supply System shall be available on this terminal.

AuxC - Display status of TVS, ECS, LV, Pumps, DG and UPS for each station / section including local equipment alarms and warnings, require acknowledgement of alarms. Allow input of commands to alter mode for TVS equipment in individual or groups of stations as appropriate to the congestion / fire situation and based on decision support system provided by TVS designer.

Allow downloading of logged running data from within the controllers of the non-power equipment being monitored, store the downloaded data and allow analysis of the data to provide long term planning of maintenance.

Electrical Supervisor – (in OCC complex)

Display real time list of LV circuits, pumps , etc. status , alarms and warnings showing local acknowledgement . Access historical list of all high level alarms and warnings showing time on, time off, time acknowledged etc..

3.3.2.2 It is envisioned that the TVS SCADA displays will take the form of separate workstations integrated alonside other workstations for other systems such as the TCS, PA/PIDS, CCTV, Radio and Telephone systems.

3.3.3 OCC Equipment Rooms

3.3.3.1 The equipment at OCC hereafter called as master station equipment shall include at least two main computers in main & hot standby configuration with latest state of art having sufficient RAM, clock speed and hard disk storage, high speed computer communication link, system console, man-machine interfaces through colour VDUs and key-boards, pointing devices (e.g. mouse or trackball), front-end processors, modems, data logging printers, watch dogs, hard disks and other storage devices along with their drives, switchover unit for switching over from main to standby computer or vice-versa.

3.3.3.2 A central database facility shall be provided to maintain a record of the status of all system database points. This database shall be updated as a continuous high-speed activity and shall be able to be accessed by any workstation within the system. It shall be possible to restrict the access of any workstation to any combination of points in the database.

3.3.3.3 A historical data storage and software backup system shall be provided that stores data in an efficient manner that permits rapid searching against selectable criteria and enables historical information to be reconstructed in the form of data.

3.3.3.4 Communications between the equipment within the OCC shall be over a duplicated communications network dedicated to TVS SCADA, which shall be provided in this contract.

3.3.3.5 RTUs shall be provided as necessary within the Equipment Rooms to interface to the other equipment located there that requires connection to the TVSSCADA system.

3.3.4 Training and Transfer of Technology

3.3.4.1 The contractor shall provide comprehensive training to the Employer's staff , including employer's trainers.

3.4 System Functional Requirements

3.4.1 The TVS SCADA system shall incorporate at least the following primary functions:

(1) Provide continuous, effective recording of data transmitted from non-power equipment.;

(2) Provide continuous, effective monitoring at OCC of all non-power equipment distributed throughout the system;

(3) Provide download of logged data on demand (may be set up as regular automatic polling

(4) provide facilities to analyze downloaded data on an historical basis and against fixed norms;

(5) Alert operations and maintenance staff rapidly to equipment malfunctions, specially those likely to cause disruption to operation of the railway and provide a facility for acknowledging the alarm.

(6) Provide clear, comprehensive displays and printed logs of equipment status to each operator workstation;

(7) Provide comprehensive reports and printed logs based upon historical data, with the option of overlaying data from earlier periods;

(8) Time-tag all events detected by the TVS SCADA system, to 20 milliseconds resolution for selected high speed inputs, and to present this information in logs as a true system-wide sequence of events;

(9) Provide control of Tunnel Ventilation System modes for individual and groups of stations;

(10) Generate routine maintenance schedules automatically, based upon elapsed time and equipment operation times;

(11) Provide centralized data storage and software back-up facilities for the complete system.

3.5 Applicable Design Standards

3.5.1 Public Standards

The practices followed and the equipment supplied under this Contract shall conform to the latest issue of local Standards, or where not available, internationally recognized Standards covering quality assurance, health and safety, fire safety, electrical safety, ingress protection where necessary, electromagnetic compatibility, design, manufacture, testing, maintainability of equipment and operation.
The following specifications in particular may be partially or wholly applicable:

3.5.2 International Standards

89/336/EEC Electromagnetic compatibility requirements.

EN 50081-2 Electromagnetic compatibility requirements

EN 50082-2 Conducted immunity level requirements.

IEC 61000-4-2 Electrostatic discharge (ESD) requirements..

IEC 61000-4-4 Fast transient burst requirements.

IEC 61000-4-5	Power surge requirements.
IEC 65	Safety standard
IEC 255-4	Electrical impulse voltage withstand test
IEC 255-4 (Appendix E)	High frequency disturbance test
IEC 287	Cable standards and cable installation standard.
IEC 332	Fire resistant requirements of cables.
IEC 364	Safety standard
IEC 364-5-529	Cable standards and cable installation standard.
IEC 571	Electronic equipment specification
IEC 68-2-6	Vibration test
IEC 68-2-31	Drop test
IEC 68-2-1	Low temperature test
IEC 68-2-14	Change of temperature test
IEC 68-2-30	Damp heat test
IEC 68-2-18	Driving rain test
IEC 870	Telecontrol equipment and systems
IEC 801-3	Radio frequency interference test

3.5.3 Foreign National Specifications.

BS 6360	Cable standards and cable installation standard.
BS 4066	Fire resistant requirements of cables.
BS7165,	
BS5515	Code of Practice for writing & presentation software.
BS6651	Lighting protection

3.5.4 Indian National Specifications

IS: 590	Fixed paper dielectric capacitors
IS: 1555	PVC (Heavy duty) insulated electric cables.
IS: 1765	Direct current Potentiometers.
IS: 3700	Essential rating and characteristics of semiconductor devices.
IS: 3895	Monocrystalline semi-conductor rectifier cells and stacks.
IS: 4007	Terminals for electronic equipment.
IS: 5051	Relays for electronic and telecommunication equipment.
IS: 5786	Fixed carbon resistors, general purpose, low power.
IS: 9521	Metal clad base material for printed circuits for use in electronic and telecommunication equipment.
IS: 9638	Fixed polyester film dielectric capacitors for direct current.
IS: 9891	Edge connectors for printed wiring board.
IS: 10482	Connectors for printed wiring board.
IS: 694	PVC insulated cables for working voltages up to and including 1100 volts.

3.5.5 Application of Standards

3.5.5.1 The above specifications shall be applied in a manner altered, amended or supplemented by this specification and the latest Indian Electricity rules wherever applicable.

3.5.5.2 Any deviation from these specification may be proposed by the Contractor if they are calculated to achieve the specified functions and improve upon the performance utility and efficiency of the equipment. Any such proposal will be given due consideration by the Employer's Representative, provided full particulars of the deviation with justification thereof are furnished. The Contractor may not incorporate any deviation from the specifications into his design until he has made the above proposal and has received no objection from the Employer's Representative.

3.5.5.3 For all parts and sections of IEC 870 ,current at the time of Contract award the Contractor shall include within the Design specification, in the form of completed tabulated lists with explanations, the class or value offered for each and every table classes or values given in the said parts and sections.

4 PERFORMANCE REQUIREMENTS

4.1 General

4.1.1 In addition, the specific performance requirements for the TVS SCADA shall be as specified herein.

4.1.2 The technical system performance requirements for the TVS SCADA are specified in the following sections.

4.2 Reliability

4.2.1 The inability to perform any required function, the occurrence of unexpected action or the degradation of performance below the specifications shall be considered as a failure.

4.2.2 MTBF shall be the average operating time accumulated by the total population of identical items between failures.

4.2.3 The TVS SCADA equipment supplied under the contract shall comply with the reliability figures given below :

N P SCADA Equipment	**MTBF (Hours)**
Central Control equipment / Server	> 50,000
RTU	> 50,000
Workstation	> 50,000

Table 4-1 MTBF Figures

4.3 Availability Requirements

4.3.1 In determining the Availability of the TVS SCADA, reliability block diagrams using field failure rates for commercially available equipment shall be produced. Any equipment without field failure data shall have its failure rate determined strictly in accordance with MIL-HBK-217F for its appropriate operating environment.

4.3.2 TVS SCADA initiated by any mode of operation shall be considered unavailable under the following failure conditions as a minimum:

(1) failure of MMI at control position at any location;

(2) failure of co-ordinated message capabilities with the RTU's at any location;

4.3.3 **Quantified Requirements**

4.3.3.1 The system shall be designed to achieve at least the following levels of system availability.

4.3.3.2 The complete TVS SCADA system shall be designed to meet 99.99% hardware availability.

4.3.3.3 The availability figures for TVS functionality and the TVS decision support facilities shall be 99.97%.

4.3.3.4 The availability figures for other TVS SCADA subsystems viz. Software Development, Historical Record searching and Training Simulator shall be 99.7%.

4.3.3.5 In determining the availability of the Delivered System, Reliability Block Diagrams using expected failure rates for commercial off the shelf equipment shall be produced.

4.3.3.6 Any equipment manufactured by the Contractor shall have its failure rate determined strictly in accordance with its appropriate operating environment.

4.3.3.7 Any degraded mode of operation or re-configuration functions provided by the Delivered System shall not be included in the determination of the Delivered System availability.

4.3.4 **Redundant design**

4.3.4.1 Redundancy shall be incorporated where failure cannot be tolerated even for short periods.

4.3.4.2 The system shall therefore be designed around small autonomous items of equipment but shall be commensurate with an economical overall solution.

4.3.4.3 Failure of any equipment node on the network shall not affect the local operation nor prevent communication between any other connected equipment node

4.4 Maintainability Requirements

4.4.1 The TVS SCADA system shall have an MTTR of 30 minutes. This time shall not include the time taken for a technician to arrive at the initial reported failure site.

4.4.2 The service life of the TVS SCADA shall not be less than 15 years. Service life shall be counted from the commencement date of Defects Liability Period.

4.5 System Safety Requirements

4.5.1 The TVS SCADA is classified as a safety related system and a minimum of CENELEC standards EN 50128 SIL-2 shall apply.

4.5.2 All equipment must comply with and be installed in accordance with IEC65, IEC364 and to current safety standards applicable in India.

4.5.3 All metal enclosures shall be provided with an earthing terminal and earthing of all equipment shall be carried out in accordance with the overall earthing policy.

4.5.4 Electrical Noise

All TVS SCADA system equipment shall operate satisfactorily in the very high “electrical noise” environment normally associated with Metro systems due to electrical fields created by traction supplies and strong magnetic fields. Equipment shall be immune to the effects of conducted and radiated electrical interference.

4.6 Lightning

4.6.1 The contractor shall ensure that all equipment are fully protected against the effects of mains surges and direct & indirect lightning strikes. Protection shall be applied to incoming mains power supplies and to input and output signal lines, to externally located sensors, transducers, actuating equipment, etc. or to any other equipment likely to be affected.

4.6.2 Lightning protection systems shall be in accordance with BS 6651 – “Lightning Protection” or an equivalent Indian/international standard.

4.6.3 All surge suppression equipment shall be self-contained and self-resetting.

4.6.4 The suppression equipment shall be so selected that the let-through voltage specification does not exceed the absolute maximum voltage specified for the particular equipment being protected.

4.6.5 Signal lines from external sensors at risk from the effects of lightning shall have surge suppressers fitted at both ends of each line and shall be installed and connected in accordance with the manufacturer’s recommendations.

4.7 Power Supplies

4.7.1 The equipment shall derive its required power from the source provided by the Contractor at stations and OCC.

4.7.2 Connection of the UPS / battery back up shall be automatic in the event of a power source failure, with no interruption in the supply seen at the equipment.

4.7.3 All alarms generated by the installation including processor alarms, power supply alarms, and control equipment alarms, shall be sustained until cleared. Alarm handling shall be implemented through the TVS SCADA system.

4.8 Remote Terminal Unit Requirements

4.8.1 RTU Functions

4.8.1.1 The Contractor shall establish the I/O requirements and provide the most economic configuration of Remote Terminal Units (RTUs) based upon cost balances between unit modularity and cabling costs for individual stations.

4.8.1.2 The RTUs shall be intelligent where necessary, fully autonomous in operation and modular in construction. The RTUs shall be configured to suit the plant input/output requirements.

4.8.1.3 The RTUs shall be suitable for either wall or floor mounting and shall be suitably robust for operation in plant room areas, to IEC529 IP65 enclosure standard. Wall mounting is preferred. RTUs shall be, as far as possible, of the same make and type at all sites and individual components shall be interchangeable between RTUs at different sites.

4.8.1.4 The RTUs shall be suitable for operating in the environment described in the GS.

4.8.1.5 The RTUs shall permit reconfiguration by the Employer of all facilities, including:

(1) Scan frequency.
(2) Signal priority.
(3) Analogue alarm level adjustment.
(4) Signal classification.
(5) Addition and removal of I/O.
(6) I/O assignment.
(7) Automatic control sequences.

4.8.1.6 The RTUs shall be able to be interrogated fully and be fully reconfigured from operator workstations and locally from a portable service terminal.

The Employer's personnel shall be able to re-configure fully the terminal unit hardware and software after completion of the training courses provided under this Contract.

4.8.1.7 It shall be possible to disable an individual RTU locally or from an operator workstation for servicing or reconfiguring without affecting other RTUs. When disabled or enabled, a change of status condition shall be announced on the Control Centre monitor and the change logged as an event.

4.8.1.8 RTUs shall operate correctly in conjunction with independent safety systems, such as hard wired safety circuits for over temperature trips, over pressure trips, electrical interlocks on packaged plant, etc. N-P SCADA equipment connected to these safety systems shall not prevent their correct and timely operation.

4.8.1.9 RTUs shall be fully autonomous in operation and shall continue to function normally in the event of failure of the Control Centre equipment, failure of any other RTU on the network or failure of the communication system.

4.8.1.10 The individual internal RTU memory shall be sized to hold, in addition to all the necessary programs, the logged input data and controls output for a period of normal operation covering a minimum of 24 hours in the event of communication failure. Operation of RTUs or any other aspect of the N-P SCADA system shall not be adversely affected as memory utilisation increases to the maximum, the design value of which shall be stated in the Design Specification (DS), prepared by the Contractor and approved by the Employer's Representative.

4.8.1.11 RTU memory shall be non-volatile, and shall be supported for a minimum period of 72 hours following power failure.

4.8.2 **RTU Hardware**

4.8.2.1 The Contractor shall ensure that the RTUs are compatible with the input/output signals from other Subsystems. Power supplies for interrogation of volt-free contract shall be provided as part of the RTU

4.8.2.2 RTU terminals shall be of the clamp type either cage clamp or screw down and shall be provided with isolating links.

4.8.2.3 RTUs shall be capable of accommodating the following input/output signal types:

Binary inputs :	12V, 24V, 50V, 110V dc 110V, 240V ac (at least 2kV isolation)
Analogue inputs :	0-10V, 0-10mA, 4-20mA dc 12 bit resolution minimum >60dB interference rejection at 50Hz.
Pulse inputs :	12V, 24V dc up to 10 pulses/sec. (at least 2kV isolation)
Binary Outputs :	volt-free contact, 12V, 24V dc, 30VA; 240V ac 125VA volt-free (relay).
Analogue Outputs:	0-10V, 4-20mA dc
Digital Serial link :	RS232/V24, RS422/V11

4.8.2.4 RTUs shall be supplied complete with 20% spare capacity for handling additional input and output signals. Expansion by at least 50% shall be possible simply by adding more I/O modules and reconfiguring the software. A further 100% expansion shall be possible by adding additional interfacing equipment in additional cabinets, etc. and reconfiguration of the software.

4.8.2.5 A manual switch inside the RTU cabinet shall be provided as a hard-wired facility to disable the operation of control outputs. Change of switch status shall be registered as a system event.

4.8.2.6 RTUs shall operate from a secure power supply. Battery voltage (analogue) and charger status of batteries used to provide the secure supply shall be monitored by the RTU. On failure of the secure supply, the RTU operation shall degrade gracefully and shall recover automatically on restoration of the supply. Supply failure shall be logged at operator workstations at OCC on restoration.

4.8.2.7 RTU Software

The RTU shall be application-software controlled, with the software assembled from proven software modules, and shall be capable of the following function and facilities:

- Local time-tagging of events.
- Alarm handling from discrete inputs and derived parameters.
- At least two adjustable alarm levels for both positive and negative excursions of all analogue signals, with adjustable deadband.
- Combining of binary inputs Boolean functions to give conditional outputs.
- Communication by serial link to other processor based equipment using one or more standard, open, synchronous or asynchronous serial interface protocols.

4.8.2.7 The equipment shall be self-monitoring for fault conditions, and shall generate an alarm on the appropriate operator workstations in the event of a fault arising.

4.8.2.8 Facilities shall be provided for routine servicing and re-configuring of RTU software by the Employer. RTU software shall be capable of being reconfigured, under password control, either locally from the portable-programming device to be supplied under the Contract, or remotely over the communications links from operator workstations.

4.8.2.9 Software re-configuring facilities shall include the following:

- Assignment of descriptive legends and engineering units to individual analogue and binary input points.
- Allocation of scan type and frequency.
- Adjustment of alarm threshold levels on analogue signals and deadband.

- Creation of conditional parameters using Boolean functions from multiple input signals.
- Classification of signals (alarms, status, etc.).

4.8.2.10 Event processing shall have the following order of precedence, but shall be re-configurable:

- Receipt of manual commands from operator workstations, each of which shall have an assignable level of command priority.
- Pre-defined control sequences.
- High speed alarms.
- Normal alarms.
- Binary events.
- Clock synchronisation.
- Analogue events.

4.8.2.11 Communications priorities shall adopt the same order of precedence.

4.8.2.12 In order to ensure data integrity, all software files contained within terminal unit equipment shall be able to be up-loaded to the Operations Control Centre and Back-up Control Centre for back-up storage as part of a master file.

4.9 OCC Control Facilities

4.9.1 Central TVS SCADA Services

- A central master computer system with hot standby at the OCC. The system shall have full redundancy both at the internal hardware level and also at the interfacing level such that no single failure should lead to shut down of the TVS SCADA functioning. Both the main and the standby systems shall be updated on a real time basis to provide seamless changeover in case of failure. The system shall be configured at the OCC on a fully duplicated link network. The hardware of the system shall be based on the proven design philosophy and shall be fault tolerant and modular. The software should based on open system concept and should have portability and inter operatibility across multi- vendor environments.

- A central database management and communications system, to communicate with the RTUs and remote workstations over the main communications link provided and to maintain a database of all system points.
- Bulk data storage facilities for software back-up and historical data.
- Workstations with high resolution colour graphics displays.
- Full function keyboards or panels with mouse units or similar.
- Printers for printing of screen displays, reports, etc. and listing events.
- Local facilities for software and data back-up.

4.9.2 The equipment shall be self-monitoring for fault conditions, and shall generate an alarm on the relevant operator's workstation in the event of a fault arising.

4.9.3 A central database shall be maintained at the OCC of the current status of all the data points. This shall be in addition to any locally maintained databases required to support full local operation at the field RTUs in the event of communication failure. The central database shall be accessible to all workstations on the system, subject to any access restrictions imposed by the system supervisor. The central database shall be able to be partitioned so that access to individual database points can be assigned on a workstation basis.

4.9.4 The various TVS SCADA workstation displays and controls shall be located within the different control desks in the OCC. Supporting printers shall be housed in custom fixtures within the OCC theatre. Central processing equipment shall be located in the equipment rooms associated with the OCC. Equipment that is not desk-mounted or otherwise free-standing shall be housed in appropriate DIN standard racking enclosed in cabinets or in a manner acceptable to the Employer's Representative.

4.10 **Work station facilities**

4.10.1 The primary operator interface shall be workstation with high-resolution LCD (TFT) colour graphics display(s), control panel and mouse/trackball units, or touch screens. Workstation shall have a screen diagonal measurement of at least 20 inch; however, the dimension shall be subject to approval by the Employer's Representative based on the screen frame display shots proposed by the Contractor. Tilt and swivel facilities shall be provided. The displays shall have the colour palette of at least 256 colours with a minimum resolution of 1024x768 pixels. The number of VDU's can be one or more but the number of VDU's for each workstation shall be sufficient to allow a comprehensive set of information to be displayed. Operating systems based on a Graphical User (GUI) format incorporating the widely used WIMPs procedures (windows, icons, menus, pointing device), where one display can overlay another shall be provided. WYSIWYG (what-you-see-is-what-you-get) display printing and print previewing features shall be provided.

4.10.2 A cursor driven by a mouse pointer or equivalent shall be provided which can be moved to any screen position under operator control. The cursor shall appear as a flashing indicator or other distinctive icon, which shall be submitted for review by the Employer's Representative, through the character at that position for the operator to identify displayed items.

4.10.3 The following primary facilities shall be available at each workstation:

- Alarm and event logging and printing.
- Operator acknowledgement of alarms.
- Selective display and printing of alarms and of events lists.
- Execution of operator commands with access code security.
- Provision of user-friendly operator sequences.
- Operator entered text messages.

- Access to historical data files of plant status.
- Generation of tabular displays based upon spreadsheets.
- Generation of graphical displays based upon graphic diagrams.
- Generation of printed reports and printed copies of display pages.
- Utilities consumption monitoring and check metering.
- Operator entered data, including tagging, manually entering values and the forcing of status points.
- Automatic logging of selected displays at specified times.
- Re-allocation/Prioritization of alarm acknowledgement between workstations.
- System timekeeping.

4.10.4 In addition to the primary operators interface within the OCC theatre, the TVS SCADA central server in the OCC equipment room shall be supplied with a secondary maintenance technicians interface workstation.

4.10.5 The CSS terminal shall have access to the main system diagnostic displays for the actual TVS SCADA equipment and the transmission links over which the TVS SCADA data travels. The CSS terminal shall be the normal terminal used for initiating software changes to the system, which may have been developed in off line mode on any terminal.

4.11 Printers and printing

4.11.1 At least one full colour page printer, or equivalent, with a page output rate of at least six pages per minute (10% imageable area) and a resolution of at least 300 dots per inch, shall be provided for creating paper copies of Workstation screen displays, reports, etc.

4.11.2 The Operator shall be able to generate a print out of any display page at any time. The print out data shall be a snapshot of the displayed plant data at the instant the print command is executed.

4.11.3 The screen display, report, log, etc. shall be spooled to the printer and the workstation shall be returned immediately to normal operation. Where the screen display is part of a multi-page log it shall be possible to select the range of pages to be printed and to cancel the print job at any time before it is completed.

4.11.4 Line printers, not impact types, shall be provided for routine logging of plant data. A line of print shall be able to be read as soon as it is completed.

4.11.5 Paper stocks, (A4 cut sheet for all printers and also continuous feed for line printers), and printed output shall be stored in hoppers. The contractor shall finalise the details regarding paper size with the Employer's Representative.

4.12 **Historical Data Storage and Software Backup**

4.12.1 A bulk data storage system with removable storage media cartridges shall be provided at the OCC for backing-up all operational and used configurable software and for historical storage of database records. Storage systems where the data can be indexed and where random rather than sequential searches are possible (e.g. optical discs rather than magnetic tapes) shall be provided. Each cartridge shall have a capacity adequate to hold all operational and user programmable software and data records for at least four weeks operation. An alarm shall be raised daily if the accumulated data and software for more than a defined period (typically one-week) has not been backed up. The bulk data storage system shall provide a master back up of all configured software and recorded data for the entire TVS SCADA system. All software files contained within the field RTUs shall be able to be up-loaded to the OCC for back-up storage as part of the master file.

4.12.2 Historical data shall be stored in an efficient manner to minimise storage requirements to the satisfaction of the Employer's Representative, such as:

- Record the history of status points by event, where each change of state is recorded together with the time tag, rather than simply by regular time interval.

- Record analogue point by recording a header with the point attribute information relating to alarm limits, scan rate etc., followed by each sample value, until the point attribute changes when another header shall be written.
- Use software to interpolate the data to reconstruct the required information, e.g. an events list, trend display, etc.

4.12.3 The historical data storage system shall index the storage media to enable rapid location of data by date and time and be able to do event searches based on selectable criteria.

4.13 Un-interruptible Power Supplies

4.13.1 Power for the OCC facilities shall be derived from the Un-interruptible power supply provided by the other Contractor.

4.13.2 In the event of breaks in the UPS supply, of sub-cycle to multiple cycle duration or long-term interruptions in the UPS output, the equipment shall continue to operate correctly, or shut down gracefully and restart automatically on supply restoration. Suitable tests shall be included in the FAT to verify compliance.

4.14 Software

4.14.1 Outline Design Basis

4.14.2 TVS SCADA software with an architecture ,enabling operation on a choice of hardware platforms is preferred.

4.14.3 Where possible, use shall be made of proprietary software packages widely used within the industry but of the latest generation at the time of installation.

4.14.4 All software shall be fully proven, including operation at maximum processing load. This feature shall be simulated during the Factory Acceptance Testing. The Operating system to be used shall include but not limited to the following features;

(1) Supports multi-tasking, multi user , inter process communication and foreground/background processing with real time capabilities.

(2) Supports virtual memory management and at least 32 bit virtual addressing scheme.

(3) Conforms to standards for Open Systems.

(4) Supports GUI.

(5) Maintains a system activity log which shall be used for system recovery.

(6) Supports all I/O devices used including high speed network protocol , TCI/IP , disk arrays, etc.

4.14.5 The application software shall consist of field-proven standard SCADA software packages that shall be configured to meet the TVSSCADA system requirements of this Specification by means of loading the appropriate entries into the standard database.

4.14.6 The TVS SCADA software shall be divided into the following basic functions:

(1) Data base management: Maintenance of the primary database for real time and historical data, signal processing and calculations. The structure of the database shall accommodate easy access of data for use in other proprietary software packages.

(2) Communications management: Support of communications protocols with comprehensive error detection and error correction facilities. Support of operating regimes, which optimize performance and operating costs on communication networks using, either dedicated or shared communications channels where operating costs can be either dependent or independent of traffic loading.

(3) Alarm and event reporting: Detection of alarms and events, support of alarm reporting and acceptance procedures on the Workstations and generation of printed logs.

(4) Peripheral management: Support of operator procedures on the keyboard and mouse units, construction of display page formats and printer page formats.

(5) Supervisory Control. Monitoring at operator workstations of equipment connected to the terminal units and manual control from the operator workstations or automatic control by pre-programmed sequences resident either in terminal units or designated operator workstations.

(6) Fault Diagnosis and Maintenance: Self-diagnosis and fault reporting to replaceable module level, notification when software back-ups are due and general housekeeping to maintain optimum operation.

4.14.7 The Contractor shall provide a “ Firewall “ in its interface with other users. This should employ various mechanisms to filter/route data traffic and block un-authorized access.

4.15 **Software Development**

4.15.1 Application software shall not be developed without the consent of the Employer other than as proposed and foreshadowed in the Tender and accepted in the Contract.

4.15.2 Where any such development is found to be necessary (including that foreshadowed in the Tender) the Contractor shall propose the development to the Employer’s Representative in the form of a fully worked development programme showing timescales and tasks to be undertaken as well as the objectives to be achieved and the methods by which their achievement is to be demonstrated. No software development work shall be incorporated into the Contract Works until the Contractor has received a certificate of no objection to his proposed development programme.

4.15.3 If the development is required to achieve a basic function contained within this specification this may be taken by the Employer as a fundamental breach of the contract.

4.15.4 Application software shall be developed using a structured “top down” approach and be presented using process diagrams, which shall form part of the software documentation in the O & M manuals.

4.15.5 Software design shall be based on a main programme structure with program modules or blocks to control each facility or function. Additions or modifications shall be executed readily by adding, deleting or replacing software modules within the main program structure.

4.15.6 All software source code shall be written in a widely supported high level language, utilising English language words, and have a simple syntax structure. All source codes shall have comprehensive comments describing fully the function of each block and the action of each program step.

4.15.7 Software shall be written and presented in accordance with the current issues of BS 7165, BS 5515 and the British Computer Society Code of Practice or other international standard. Technical terms and documentation shall be in accordance with “Guidelines for documentation of software in industrial computer systems". Institution of Electrical Engineers, UK or its international equivalent. All application software shall be written and documented such that changes to facilities and operating procedures may be implemented readily by the Employer’s personnel after completion of the training courses.

4.15.8 On completion of the development, all software shall be tested in the equipment being provided under this Contract at the Suppliers workplace to a test schedule based on a Design Specification (DS), prepared by the Contractor and reviewed with no objection by the Employer’s Representative.

4.15.9 Once the testing is completed to the satisfaction of the Employer and the Employer’s Representative and the software amended to incorporate any changes required, the software shall be subject to a design freeze and all associated documentation changed from letter issue status to number issue status. The documentation will then be subject to approval by the Employer and the Employer's Representative.

4.15.10 Software shall be supplied on a non-volatile removable storage medium such as magnetic tapes, optical disk, etc. (not $5^1/_4$" magnetic discs or any other type with exposed media). Six copies of the software and supporting documentation shall be provided to the Employer reflecting the "As built" system status at completion. The Contractor shall also retain and archive further master copies to support the software maintenance contract.

4.15.11 All software media shall be clearly labelled with the program name and issue status. The information shall also be listed in the O & M manuals.

4.16 **MMI Requirements**

4.16.1 **Database facilities**

4.16.1.1 Each monitored point shall have a point descriptor and shall have a number of attributes that may be modified by the operator.

4.16.1.2 Any attribute of any system point shall be able to be modified using reconfiguration pages by an operator with sufficient access rights from any workstation.

4.16.1.3 The point descriptors shall contain at least the following information:

- Point identifier.
- Point type (high-speed status, normal status, analogue, calculated, manual entry, etc.).
- Normal state.
- Alarm type.
- Time delay on alarm.

4.16.1.4 For analogue points:

- Conversion constants.
- Engineering units.

- Alarm limits.
- Scaling
- Rate of change limits.
- Deadbands.
- Scan rate.

4.16.1.5 Points shall be able to be assigned for historical storage. Configurable filtering parameters shall be able to be applied to the storage of historical data, which shall be stored together with the historical data.

4.16.1.6 Raw analogue input data shall be converted and stored in the database in engineering units. Manipulation of measured values, for linearisation, etc. shall be possible using a calculation facility.

4.16.1.7 Status points shall be configurable as either discrepancy types, with a normal state such that a deviation from this state shall generate an alarm, or as standard types with no normal state or as four-state points, where two ordinary status inputs are combined. Filtering shall be able to be applied to four-state points to prevent spurious transitional states being registered.

4.16.1.8 Provision shall be made to allow the operator to inhibit the acquisition of RTU data at a point level or RTU level.

4.16.2 Workstation Displays

4.16.2.1 All operator displays shall be based on a common screen layout. The screen shall be divided into the following display zones:

- Home Cursor Position.
- Display identifier.
- Page Number
- Date and Time
- Title Line
- Information Display Zone.
- Error Message Line.
- Alarm banner.

4.16.2.2 Workstations shall have sufficient storage capacity for at least two hundred different display pages.

4.16.2.3 The following general display page groups shall be provided in addition to any other groups required:

- Master index display.
- Log index display.
- Alarm display.
- Points Off Normal display.
- Tag list display.
- System Status display. (Graphic Display)
- Communications statistics display.
- Parameters display.
- Scratch Pad display.
- Trend Assignment display.
- Selected-log-entry display.
- Operator information display.

4.16.2.4 These display groups shall be divided into display pages. Each group shall be accessed by a dedicated function key (or equivalent). Dedicated keys shall be used for paging forward and back through each group. Individual target areas (menu points) shall be configurable on to each display unit which, when operated, shall bring up a predefined display from any group.

4.16.2.5 The Master index shall list all the displays authorised for access by the current operator at the particular workstation, by display group and display identifier. Any display in the Master Index shall be accessible through the use of menu points associated with the display title. The workstation shall output either the desired display or another index display. It shall be possible to have at least 16 levels of nested displays.

4.16.2.6 The Log Index display shall be accessed via a dedicated function key. This display shall list all of the logs that the system produces and the frequency with which they are generated. This display shall be used to generate a log on demand or to schedule or inhibit automatic periodic output.

4.16.2.7 The Alarm display shall be provided in accordance with the Alarm Clauses below.

4.16.2.8 The Points off Normal display shall list all variables that have been inhibited from normal acquisition or calculation, including being inhibited by the operator.

4.16.2.9 The Tag display shall list those points that have been tagged by the operator together with the tag type, description, etc.

4.16.2.10 The System Status display shall show the status and of all hardware components in the TVS SCADA system including the terminal units and secure power supplies. The system status (or parts of the system status) shall be displayed as the workstation Graphic Display described below.

4.16.2.11 The Communications Statistics display shall tabulate the number of successful and unsuccessful communications between each node on the system, identifying the communications route.

4.16.2.12 The Parameters display shall provide a complete point descriptor for each status, measured and derived point in the system.

4.16.2.13 The Scratch Pad display shall be used by the Operator to record comments and messages pertinent to events during his shift or to general operating policy. He shall be able to write anywhere on the one page display, overwriting or deleting messages as desired.

4.16.2.14 The Trend Assignment display shall be provided for the assignment of any analogue point in the system.

4.16.2.15 The Select-Log-Entry display shall enable the ACC or AuxC to display appropriate selected entries from any of the system logs (events, alarms, etc), with the option of including historical data, against operator-definable selection criteria. An indication of the percentage of the log(s) searched shall be displayed, together with facilities to halt or cancel the search.

4.16.2.16 Operator Information displays shall be provided for operator information complete with indexing, selection and editing facilities.

4.16.3 Graphic Display

4.16.3.1 VDU-based graphic displays shall be used to provide the operator with information that can be easily and intuitively understood, about current network data and the TVSSCADA system status. For maximum clarity of presentation, consistent use of colour shall be used for all displays. In particular, a colour change shall be used to identify different point statuses and plant data in an alarm state.

4.16.3.2 Graphic display selection shall be hierarchical to increasing detail from an overview of the complete network, which shall serve as the default display.

4.16.3.3 Full use shall be made of graphical displays showing plant diagrams overlaid with current plant data to provide the operator with rapidly understood information for monitoring current plant status. A hierarchical system of access to increasing detail shall be used, for example:

- Station Area comprising platform level, concourse level or inter-station area;
- Public areas of each level, equipment rooms at each level;
- Different zones of fire detection or smoke extraction systems;
- Individual items of equipment e.g a single escalator.

4.16.4 Other Displays

4.16.4.1 Tabular presentation of system data shall be based upon spreadsheets. These shall also be used to generate periodic logging formats for printing. Tabular displays shall include current equipment status reports.

4.16.4.2 The system shall also provide pre-formatted tabular, spread sheet and bar chart displays of individual and related groups of signals, based upon current, historical and calculated data.

4.16.4.3 Displays of plant running times over user selectable time periods for all monitored plant shall be provided.

4.16.4.4 All points shall have an attribute that can be set to indicate the normal state of the point. If set, the point descriptor shall be listed on the Off Normals display page in reverse chronological order when the point is not in the normal state. Other conditions that shall cause points to be listed here shall include points in test, under manual control, alarm inhibited, etc. Points shall be removed from the list when they resume normal status. Points entering and leaving off-normal status shall be logged in the event list.

4.16.4.5 The operator shall be able to tag database points. Points that are tagged shall be identified by a special symbol or code adjacent to the point display symbol.

4.16.4.6 A tag summary display shall be provided listing current tags for the complete system or selected groups.

4.16.4.7 It shall be possible to remove tags from points from this display. At least ten tag types shall be able to be defined by the operator, including definition of the tag symbol, descriptor, effect of tag (e.g. inhibit control), etc.

4.16.4.8 Facilities shall be provided on workstations for time trending of selected analogue points. Each point shall be plotted on a graph with the measured variable scaled on the Y-axis and real-time scaled on the X-axis. Each scale shall have adjustable minimum and maximum values. At least four points shall be assignable to a graph and each variable shall have a dedicated measured-variable axis scale. Each plot and associated axis shall be distinguished by colour and shall have the point descriptor written adjacent to the graph. Options to display the graph as either data points only, data points linked by straight lines or linked by a smoothed interpolated graph shall be operator selectable. The data shall also be able to be displayed in a tabular format and as an ASCII character computer file suitable for insertion into a spreadsheet or similar.

4.16.4.9 A trend display shall be defined by the following attributes:

- Chart origin.
- Measured-variable scale.
- Time scale.
- Pen definition.

4.16.4.10 All analogue database points shall be assignable to trend displays

4.16.4.11 Timescales for trends of historical data shall be the actual time period the data was obtained and any filtering parameters that were applied. It shall be possible to re-scale the time axis and the measured-variable axis to enable any historical data to be overlaid on to any other trended data. Facilities for scrolling the trend display along the time axis shall be provided.

4.16.4.12 Operator information displays shall be provided which shall comprise: operating instructions, general information, and equipment information and management instructions.

(1) Operating Instructions: shall consist of general operating instructions relating to particular stations with direct selection of the operating instructions for a particular station by use of a menu point on the line diagram display of that station.

(2) General information: shall consist of general information, e.g. telephone numbers, etc

(3) Equipment Information: shall consist of databases of information related to the main items of equipment, such as, identification number, type, make, location, and reference drawings etc.

(4) Management instructions: shall consist of particular instructions for implementation of specific application software.

4.16.5 Display Construction

4.16.5.1 A display building facility shall be provided to create, delete and modify display pages for all the types of display described.

4.16.5.2 The display builder software shall be a user-friendly, permitting picture to be built up using all combinations of fixed background and with foreground data fields using real time, historical or calculated data.

4.16.5.3 Both static and dynamic symbols shall be obtained from a library of symbols with each symbol referred to by a unique identifier. Symbols shall be able to be deleted from or created and added to the library. All workstations shall use the same library of symbols, or a locally retained copy that is periodically updated from the central library, when building displays. It shall be possible to construct displays on-line without interrupting normal N-P SCADA operations.

4.16.6 **Alarms**

4.16.6.1 An alarm shall be generated when an analogue, binary or derived value enters a pre defined alarm condition. To prevent spurious alarms, adjustable deadbands on analogue alarm limits and user-definable filtering on binary alarms shall be provided.

4.16.6.2 One line on the display page shall be reserved for the display of alarm messages (the alarm banner). Alarms shall be classified into priority groups, for example:

- Urgent alarms requiring immediate attention.
- Alarms requiring attention within a user defined period.
- Non urgent events or operator guidance messages.
- Alarms affecting periodic maintenance schedules.
- System housekeeping alarms.

4.16.6.3 When an alarm is received it shall appear flashing on the alarm banner of the appropriate workstation as a text message, with an audible warning and flashing of the button of the display group relating to the alarm and copy the text message into a separate alarm text page which shall list the alarms in reverse chronological order. When the display group button is operated ,a predefined but configurable display page shall be displayed on the workstation. Acceptance of the alarm by the operator shall cancel the flashing display to steady, silence the alarm. The alarm banner shall be overwritten by the next alarm message. System providing priority group identification by colour change is preferred. The alarm text pages shall be selectable at any time.

4.16.6.4 In addition to plant alarms, all TVS SCADA system alarms such as RTU unit failure, communication failure etc., shall generate alarm messages.

4.16.6.5 Alarm messages shall contain date and time - time tagged with time in hours, minutes and seconds, and milliseconds for high resolution alarms, point identifier, signal value, alarm message text and priority group.

4.16.6.6 An unacknowledged alarm and an alarm acknowledged but with the condition not reset shall be distinguished by colour and by various groups of characters flashing. Reset alarms shall be steady.

4.16.6.7 All alarm attributes shall be authorised operator adjustable while online.

4.16.6.8 Alarms for analogue database points, both monitored and calculated, shall have two independently pre-set but adjustable alarm limits for both high level and low level excursions outside the normal operating range and for rate of change, together with a pre-set but adjustable deadband on each threshold.

4.16.6.9 Analogue alarm messages shall also display both the current value and the limit being violated.

4.16.6.10 When the analogue point value returns to the normal operating range, a return-to-normal message to this effect shall be generated. The message shall indicate the point returning to normal but without displaying the value. The audible alarm warning shall sound for an independently pre-set but adjustable period.

4.16.6.11 When the value of a status alarm returns to normal, a return-to-normal message to this effect shall be generated. The message shall indicate the point returning to normal and its present state. The audible alarm warning shall sound for an independently pre-set but adjustable period.

4.16.6.12 It shall be possible to acknowledge alarms individually or in-groups from the alarm display page. Alarm acknowledgement shall be time tagged.

4.16.6.13 Alarm filtering shall be provided to avoid unnecessary and uncalled for alarms. The features that shall include :

(1) Time delay - pre-set but adjustable time delay on-entry to the Alarm State before the alarm is raised.

(2) Alarm blocking - facility to inhibit alarms, at a particular workstation or globally, depending on the state of other points or on operator command. Inhibited alarms shall behave as non-alarmed points but shall be listed on the Off-Normal display page of the terminal units affected.

(3) Equipment under test - facility to suppress alarms generated by testing.

4.16.6.14 A date line shall be inserted in the alarm list to divide up the alarms into days.

4.16.6.15 The Contractor shall provide sufficient non-volatile memory to hold all alarms occurring over a 4 week period and shall provide, as part of the software, an operator prompt to archive alarm details and an in-built alarm to advise the operator when the non-volatile alarm store reaches 90% of its capacity.

4.16.6.16 Alarm text pages shall be able to be printed as a routine log.

4.16.7 **Event Logging Reports**

4.16.7.1 A central logging system shall be provided to record the following events:

- Change of state of a terminal unit binary input.
- Changes to the configuration of central database and communications system.
- Changes to the workstation configuration (to be recorded on the local event printer only).
- Alarm events.
- Manually entered changes.

- Control actions, manual or automatic.
- Operator - entered text messages.
- System generated messages, e.g. equipment malfunctions.

4.16.7.2 Events shall be listed in true reverse chronological order with the latest event at the top of page-1, while at least the most recent 500events shall be available for immediate display. It shall be possible for the operator to select 'page reverse chronological order' where the pages are in reverse chronological order but the alarms on the pages are in chronological order. A further 1,000 events shall be available for delayed display. The date, time of occurrence and an event descriptor shall be displayed for each event. Additionally, the operator ID shall be recorded for each operator-initiated event.

4.16.7.3 True system-wide sequence-of-events recording, to 20 millisecond resolution for high speed alarms, shall be provided, by frequent automatic synchronisation of Terminal unit clocks with the Master clock at the OCC , so that events can be accurately time tagged by the Terminal units. Tests shall be carried out as part of the Factory Acceptance Tests to confirm compliance with this requirement and particularly to verify correct sequencing of large quantities of high-speed alarms detected over several sites. The TVS SCADA system master clock shall be synchronised to the JMRC master clock system, by using the interface provided at the OCC.

4.16.7.4 Facilities shall be provided for generating printed reports. The reports shall be operator configurable and shall enable any of the information in any of the display groups to be printed out, either on demand or on a scheduled basis.

4.16.7.5 Flexibility of report content and layout shall be provided by the capability to build up reports from the pages of one or more display groups based upon current, historical or calculated data.

4.16.7.6 Reports shall include pre-formatted routine logs of plant data, scheduled by date, day, month, defined period, etc. or on demand.

4.16.7.7 Printed schedules shall also be able to be generated when requested for routine maintenance of the monitored equipment. The schedules shall be based upon the manufacturers' service data and the elapsed running time/operations data for the equipment. The Contractor shall liase with the Contractor supplying the respective equipment to obtain the relevant data for inputting into the TVS SCADA system to derive the Schedules.

4.16.8 **Calculated and Derived Value**

4.16.8.1 All common mathematical functions shall be available in the calculation facility for generating calculated and derived values.

4.16.8.2 Updating of calculated values shall be configured to be initiated periodically, on demand, upon the occurrence of a system event or in any combination of these. Calculation algorithms shall be table or list driven. Algorithms shall be constructed, deleted, or modified using easily understood techniques requiring no specialist programming knowledge.

4.16.8.3 Calculated values shall be stored in the database as a point and shall be equivalent to point data retrieved from terminal units.

4.16.8.4 The capability for the operator to enter data manually shall be provided, by forcing a point status or analogue value or by other means, for use in calculations, printing on logs, and presentation on workstation displays. Forced points shall display the current value being used by the system. The operator shall be able to suspend calculation of any calculated value in the system.

4.16.8.5 Measured, calculated, and manually entered data shall be clearly distinguished in displays, logs, etc.

4.16.8.6 Both Boolean logic and numerical calculation facilities shall be provided. The number of calculated points available shall be at least equal to the number of field-derived points.

4.16.8.7 The operator shall be able to enter a new value for any system variable from any display on which it is shown. Input values shall be confirmed as consistent and reasonable. Input errors shall be identified to the operator with guidance given on rectifying the error. Changes to system variables shall be recorded on the event log.

4.16.8.8 Manually overriding a calculated or measured variable shall suspend the normal updating process for that variable until the operator removes the manual override.

4.16.9 Access Security

4.16.9.1 To access the system, the operator shall log-on using a security access code that shall be masked on the display when being entered. Codes shall be assigned to individual operators based upon the following suggested access levels**:**

- Read all data.
- Read all data and plant control facilities.
- Facilities as above with access to modify non-critical parameters.
- Full system access.

4.16.9.2 It shall be possible to suppress any or all of the access security features at each level but only from the highest level.

4.16.9.3 If no terminal activity is detected for a user-defined period, access shall time out.

4.16.9.4 Log-in and log-out of all users shall be recorded by date, time and user ID on the event list, as shall any configuration changes to the system.

4.17 Speed of Operation

4.17.1 The system shall be considered for test purposes to have a Normal operating state and an Avalanche operating state. These are considered for test purposes to be representative of typical states however it shall be the responsibility of the Contractor to undertake his own estimation of the activity on the system and to provide sufficient capacity to cater for normal and heavily loaded cases.

4.17.2 **The two state definitions are as follows:**

- Normal – A typical rate of 5 alarms per minute and with bursts of up to 50 alarms, occurring not more frequently than at two minute intervals. Each VDU and keyboard is to have user requests at the rate of three per minute. All other functions including picture building and database amendment shall be available without performance degradation. 'Normal' operation is expected to be applicable 24 hours per day 365 days per year.

- Avalanche – An inrush of 500 alarms followed by alarms occurring at a rate of 100 every 20 seconds for a period of two minutes.

4.17.3 **Change Responses**

4.17.3.1 Maximum time between occurrence of an alarm at RTU and completion of graphical display of the alarm at a workstation. Normal Operation in 1s. Under avalanche conditions, Operation in 2s.

4.17.3.2 Maximum time between occurrence of an alarm at RTU and occurrence of an audible alarm with indication and identification. Normal Operation in 1s. Under avalanche conditions, Operation in 2s.

4.17.3.3 Maximum time to update an analogue input from it passing out of its 'jitter' range at RTU to completion of display at a workstation. Normal Operation in 5s. Under avalanche conditions, Operation in 10s.

4.17.3.4 Maximum time for an accepted alarm to be indicated on the appropriate display. Normal Operation in 1s. Under avalanche conditions, Operation in 2s.

4.17.3.5 Maximum time to initiate a 'select' command and receive the check back acknowledgement from the RTU at the Control Room workstation. Normal Operation in 1s. Under avalanche conditions, Operation in 3s.

4.17.3.6 Maximum time to initiate an 'execute' command and receive a confirmation back at the Control Room workstation. Normal Operation in 1s. Under avalanche conditions, Operation in 2s.

4.17.3.7 Worst case time includes the simultaneous execution of batch reports. These reports shall carried out as a background task and shall not affect the operation of the system in any respect.

4.17.3.8 Maximum time from any keystroke to a reaction by the system (e.g. VDU echo). Normal Operation in < 0.3s. Under avalanche conditions, Operation in < 0.5s.

4.17.3.9 Maximum time from last keystroke in a transaction to some form of display to user to indicate that the system is responding. Normal Operation in <0.5s. Under avalanche conditions, Operation in 1s.

4.17.3.10 Maximum time from last keystroke to complete display of most complex base picture. Normal Operation in 1s. Under avalanche conditions, Operation in 2s.

4.17.3.11 Maximum time from last keystroke to complete display of a VDU picture with a minimum of 10 live points. Normal Operation in 1.s. Under avalanche conditions, Operation in 2s.

4.17.3.12 Maximum keyboard/mouse response time. Normal Operation in >0.5s. Under avalanche conditions, Operation in 1s.

4.17.3.13 Maximum time for a server which is in standby mode to reach full operational mode. Normal Operation in 1s. Worst Case Operation in 3s.

4.17.3.14 Maximum time for a master server which is totally shut down to reach full operational mode. Normal Operation in 2 min. Worst Case Operation in 5 min

4.17.3.15 The maximum time from request for a report to be printed, where it only involves look-ups from the database for a maximum of 1000 printed records, even during polling and alarm conditions shall be 10 min.

4.17.3.16 The maximum time to refresh any input status shall be stated in the DS by the Contractor and approved by the Employer's Representative, however the maximum interval for updating of any input status shall not be more than 3 minutes

4.17.3.17 Printing or trending functions shall not degrade the performance of the N-P SCADA system as outlined above.

4.17.4 **System Loading**

4.17.4.1 The TVS SCADA system shall meet the performance criteria in three broad categories viz. Response, Loading & Capacity and Accuracy & resolution

4.17.4.2 The CPU at any server shall not be busy for more than the following proportion of time measured over any 5 min period. Normal Loading 35%. Worst Case Loading 70%.

4.17.4.3 The disc capacity at any server shall not be filled to more than the following proportion of capacity. Normal Loading 35%. Worst Case Loading 50%.

4.18 **Time Synchronisation**

4.18.1 TVS SCADA shall have an internal clock synchronised to the Master Clock System provided as part of FOTS for the time and date information. The internal clock shall allow free running in case of loss of signal from the Master Clock. On restoration of the Master Clock, the internal clock of the TVS SCADA shall synchronise back to the Master Clock system.

4.18.2 Maximum time difference between the clocks in any two devices at the same location shall be 10 milli-seconds.

4.18.3 Maximum time difference between the clock at any RTU and that at any server shall be 10 milli-seconds.

4.19 **Accuracy**

4.19.1 Maximum error of analogue signals from the input to the Analogue to Digital Converter (ADC) at the RTU to value stored or displayed at master server shall be 0.1%.

4.19.2 **The event time tag shall have a resolution of ten milli-seconds.**

4.20 Historical Data Management

4.20.1 An historical database shall be maintained which shall be supported by the same facilities as provided for current data, except that the time period shall be user definable. Displays generated from historical data from different time periods shall be able to be overlaid on one another and overlaid on displays of current data.

4.20.2 Historical data shall be able to be manipulated as if it were current data, namely be usable in calculations and on tabular, trend, graphic, spread sheet and bar chart displays. Data stored on multiple bulk storage media cartridges shall be able to be analysed, with the system providing prompts for cartridge changes.

4.20.3 The Control Centre operator shall be able to define the signals assigned to the historical database. It shall be possible for the operator to set up calculations based upon historical data e.g. averages, maximum values, minimum values, totals etc., over a defined time period.

4.20.4 The ability to display formatted current data alongside independently formatted historical data shall be provided.

4.21 Communication System

4.21.1 OCC to Field Communications

4.21.1.1 Communications between the OCC TVS SCADA main server and the RTUs to be provided The Contractor shall supply and install as part of this system suitable interfaces to the termination points provided at each station.

4.21.1.2 The communication systems shall comprise dedicated communication cables (except for the main communication bearer) and interfaces, suitable for the environment, run locally in the OCC and within each station and run to all RTUs, workstations and to the main FOTS communications link.

4.21.1.3 The communication cables shall be able to share troughs and tray / trunking with cables for other communications services.

4.21.1.4 Communication software in each RTU or workstation node on the network shall enable peer-to-peer operation, such that failure of any node shall not affect other nodes on the network.

4.21.1.5 The transmission data rate shall be determined by the Contractor based on the required response times (see clause 4.17 above).

4.21.1.6 Error checking and correction techniques shall be a communication protocol, to ensure techniques shall be an inherent feature of the data integrity, which is transparent to the Operator.

4.21.1.7 The healthy operation of all RTUs shall be verified at intervals not exceeding 30 seconds. RTU or communication link failure shall be displayed on the appropriate workstations as a system alarm.

4.21.2 **Local Station Communications.**

4.21.2.1 Local TVS SCADA communications links from the RTU 's within stations shall be provided as part of the TVS SCADA system. All cabling from the RTU's up to the Interface Cabinet terminals for the equipment being monitored shall be supplied and installed by the Contractor under this Contract.

4.21.2.2 Local communication systems shall comprise dedicated communication cables suitable for the environment, run locally within each station and run to all field equipment Interface Cabinet terminals. Local communication cables shall be able to share troughs and tray / trunking with cables for other station services.

4.21.2.3 In the event of a failure of the main communications system, local operation between the RTUs and the equipment to be monitored at each station shall be maintained. Updating of the central database at the OCC shall take place immediately on restoration of the communications link.

4.22 Communications within OCC

4.22.1 Communications within the OCC complex will be provided as a part of TVS SCADA system. The Contractor shall supply and install as part of this system suitable interfaces to the termination points provided at each equipment server computer or workstation.

4.22.2 The communication systems shall comprise dedicated communication cables and interfaces, suitable for the environment, run locally in the OCC and run to all RTUs, workstations and to the various main equipment network servers.

4.22.3 The communication cables shall be able to share troughs and tray / trunking with cables for other communications services.

5 DESIGN REQUIREMENTS

5.1 Ergonomic Study

5.1.1 It is envisioned that the TVS SCADA displays will take the form of separate workstations integrated alongside other workstations for other systems such as the TCS, PA/PIDS, CCTV, Radio and Telephone systems

5.1.2. The results of the Ergonomic Study shall be presented to the Employer's Representative for review with the preliminary design of the OCC theatre layout and list of proposed equipment for each operators position.

5.1.3. In particular the design and positioning of the mimic displays within the OCC shall be such that the information of interest to each operator is visible from their normal position. Larger characters shall be used for legends, which require to be read from further than the first position from the mimic display.

5.1.4. The Ergonomic Study will therefore not be considered as complete unless it is accompanied by a study of the actual functional information requirements of each operator's workstation.

5.2 Screen Graphic displays

5.2.1 The workstation screen displays at the OCC shall be identical except where they describe the location of the operator within the overall system.

5.2.2 Status indication and equipment control facilities provided shall be in accordance with the Employer's Requirements and shall be determined in detail in respect of the various systems to be monitored / controlled.

5.2.3 All screen graphic display layouts shall be submitted to the Employer's Representative for review initially in the form of drawings followed by representative screen shots for each display.

5.2.4 Whilst a finding of no objection to an initial drawing of a screen display provides cause for the Contractor to continue towards development of the actual screen layouts the Employer reserves the right to object to the screen display developed from the drawing.

5.2.5 The basic functions capable of being undertaken, using the monitored and historically recorded data from the field equipment, on the TVS SCADA workstation displays are tabulated below:

Category	Functions	
	Specified Categories	**Description**
	CRT- based supervision	Window functions are available, enabling display of plural supervisory screen at the same time

Category	Functions	
	Specified Categories	**Description**
Monitor and Supervision	1) Status display of units	Displaying position symbol of units with shape, colour, flickering
	2) Fault display	Displaying position symbol of units with shape, colour, flickering
	3) Telemetry value display	Displaying major telemetry values of voltage, current etc.
	4) High/Low limit check	Supervision and display of deviation of voltage, current and such telemetry data from High/Low setting values.
Control	1) Individual control	Control individual units by dispatcher's judgement
	2) Plural control Individual plural-action control Fault isolation-action control	Selective control of individual units by plural action operation (Selective-Before-Operation)

Category	Functions	
	Specified Categories	**Description**
	3) Scheduled-pattern control	Control of routine operation by scheduled-pattern as in the case of cut off power at the time of closing train operation at night. Automatic operation suspended for items tagged as being under maintenance with work in progress.
	4) Functions with controls Miss-operation preventive Check Virtual position control	
Record and Reporting	Reporting management	Automatic collection of various achievement data, for editing and listing of operational achievement documents.
	Daily Report	Reporting and printing out a daily report of data arising from hourly telemetering and incidence occurrence.
	Monthly Report	Reporting and printing out a monthly report of data arising from daily report.
	Annual Report	Reporting and printing out an annual report of data arising from monthly report.

Category	Functions	
	Specified Categories	**Description**
	Message summary record	Reporting and printing out a message list, supported by sorting and editing functions based on specific factors, such as time and facilities.
	Message list record	Reporting the contents of equipment operation, status change and alarming log.
Measurement and Statistical Function	1) Trend graph display	Measuring of the telemetry items (instantaneous or integral values) according to the measuring period, displaying on the screen in the form of trend graphs.
	2) Real time	Displaying real-time data in trend graphs; Available only for instantaneous values.
	3) Historical	Displaying historical data in trend graphs; Available only for instantaneous and integral values including maintenance record.
Other Functions	Change over remote control to manual control and vice versa	

Category	Functions	
	Specified Categories	**Description**
	Right-of –operation supervision and setting. Security protection	Security protection by log-on password checks (operators, System managers, Programmers).
	Operation privilege setting	Setting up the scope of right-of-operation with a user name, to cover supervisory control objectives.

Table No. 5-1 Field Status and Control Interfaces

5.2.6 All field equipment interfaces shall be capable of being designed such that it shall be possible to transfer data both to and from the TVS SCADA over individual terminals using voltage free contacts and analogue transducers.

5.2.7 Where Binary (ON / OFF two state) signals are to be transmitted then the equipment on the side of the interface receiving the information shall provide the power supply and the equipment on the sending side shall provide the voltage free contacts.

5.2.8 Where Analogue signals are to be transmitted then the equipment on the side of the interface sending the information, shall provide the power supply.

5.2.9 The parameters to be monitored for the different field equipment systems are described in the attached Appendices W to Z.

5.2.10 The field equipment suppliers may propose to use a digital serial link instead of binary and / or analogue signals. In this case they shall propose a protocol, which complies with a recognised, open, publicly available standard. The TVS SCADA Contractor shall attempt to make use of any such digital interface proposal, which matches the capabilities of the equipment he proposes.

5.2.11 The TVS SCADA Contractor shall supply and install all cabling, surge/lightning protection devices, cable routes, glands, cable supports and cable markers from his equipment up to the terminals within the Interface Cubicle supplied by others in the equipment room where the Interface Cabinet is installed.

5.2.12 The TVS SCADA Contractor shall undertake the lead in defining the actual data points to be transmitted across the field interface by providing a format for interface tables to be filled in by the field equipment supplier. The field equipment supplier shall be responsible for providing the information required including, but not limited to, nominating the terminal numbering, interface type (binary, analogue, etc.) data nomenclature and, for digital serial links, message protocol including headers, error detection and data layout within the message packets.

5.3 OCC Status and Control Interfaces

5.3.1 Within the OCC, the major status interfaces are with the network management processors for other systems also supplied by the other Contractor.

5.3.2 The Contractor shall determine the necessary inter processor links and data transfer protocols. It is preferred that only one type of inter processor link and data transfer protocol is used within the OCC equipment room. A network-based solution based on TCP/IP network addressing and protocols is preferred.

5.3.3 The Contractor shall propose a complete list of all the inter processor links and data transfer protocols within the OCC for review by the Employer's Representative as part of the conceptual system design process.

5.4 Field Equipment to be monitored

5.4.1 The Contractor shall undertake an interfacing process with the contractors supplying the field equipment to identify the final number and form of data items to be monitored and the necessary form of controls to be transmitted to the field equipment to initiate and confirm transfer of data to the TVS SCADA.

5.4.2 The attached drawing “Control System Block Diagram” shows a typical arrangement of control and indication links at a filed location.

5.4.3 The items to be transmitted over the TVS SCADA include, but are not limited to, the entries in the following clauses.

5.4.4 Fire Detection and Alarm Interface

5.4.4.1 The following items for each station shall be monitored and abnormal conditions shall be alarmed:

- Main station fire panel healthy.
- Fire Alarm condition.
- Zone of reported fire.
- Non-synchronising to local clock.

5.4.5 Low Voltage Circuits Interface

5.4.5.1 The following items for each station shall be monitored and abnormal conditions shall be alarmed:

- Main switchboard LV outgoing circuit breaker status.
- Protection relay operation.
- Dual supplies healthy; all areas.
- Emergency lighting fault status.
- UPS Status (I/O voltage, indication, and position of bypass switch & battery voltage).
- Operation and status of pump and water levels in seepage sumps and other tanks.

- Operation and status of DG set, battery voltage for starting.
- Alarm in case a pump or a DG set has not run during the last seven days.

5.4.5.2 Not Used

5.4.6 Environmental Control System Interface

5.4.6.1 Sufficient indications of plant state shall be logged and transmitted to the OCC to permit a full analysis of plant running / fault conditions and also to provide adequate indication in the OCC that all operational and safety related equipment are operating in desired manner.

5.4.6.2 The following list identifies some, but not necessarily all items, which shall be monitored in the OCC or SCR, for which abnormal conditions shall be alarmed.

(1) The status of the local control switch and starter power isolator switch shall be monitored to ensure that fans are operable from the SCR.

(2) Station return air fans / trackway exhaust fans, air handling unit fans and associated dampers.

(3) Control air pressure (if utilised)

(4) Chilled water pumps

(5) Individual chillers

(6) Air handling unit filter pressure drops.

(7) Condenser water flow.

(8) Condenser water temperature “in and out” of chiller.

(9) Plant room space temperature.

(10) Station temperature, pressure and humidity.

5.4.6.3 The condition of the following points shall be monitored and measured, and coded values transmitted.

(1) Chilled water flow.

(2) Chilled water temperature “in and out” of chiller.

5.4.6.3.1 See also the contents of Appendix X for the items in particular to be monitored at OCC.

5.4.7 Tunnel Ventilation System Control and Monitoring

5.4.7.1 Operating Scenarios

The TVS Contractor shall develop operating scenarios for normal, congested and emergency situations and shall provide control sequencing to provide for safety of equipment and passengers during emergency situations especially during evacuation of passengers.

5.4.7.2 Control System Interface

The local control system for the TVS shall be designed to receive control mode commands from OCC, to control the TVS equipment to the desired conditions and report equipment status, including operation alarms, to the OCC via N-P SCADA and to the Ventilation Control Panels (VCP) in the local SCR. Local information transfer within the TVS equipment and with other systems on the station will be the responsibility of the relevant Contractors and will not make use of the N-P SCADA system.

5.4.7.3 **Control and Monitoring at OCC.**

5.4.7.3.1 The control and monitoring of the TVS equipment at the OCC shall be via the N-P SCADA. The TVS Contractor will provide the data necessary so that the following functions can be performed by the Auxiliary System Controller (AuxC) using the N-P SCADA workstation at the OCC:

- To provide operating command modes and set points to the TVS Local Sequence Controllers.

- To provide individual or group start/stop and indicate status of TVS equipment.
- To provide centralised logging of selected TVS equipment including periodic reports on usage as well as program maintenance guides.
- To indicate and log alarms such as high temperatures, equipment fault/failure, etc.
- To provide Daily Report, Weekly Report, Monthly Report of total energy consumption and Operating Hours Report of all TVS equipment.
- To indicate and log the operating status and alarm conditions of the TVFs, TBFs, TEFs and their associated dampers, tunnel ventilation system bypass and isolation dampers, MCCs and emergency stop push button.
- To provide remote control for the TVFs, TBFs, TEFs and their associated dampers.

5.4.8.3.2 The TVS Contractor will provide necessary hardware, software, data, etc., for each station so that the following control and monitoring functions for the TVS can be performed:

- To initiate operation of the tunnel ventilation system from the OCC in response to train congestion operations resulting from a delay or operational problems, which prevents the free, flow of trains through the system. When a train stops in a tunnel due to congestion on the running line and when the tunnel temperature rises above a pre-set value, the relevant TVS operation mode shall be activated by a command via the TVS SCADA, which is referred to as the “Demand Signal”. The Demand Signal will be selected by the AuxC operating the TVS SCADA workstation.
- To initiate operation of the TVS in response to emergency operations which generally result from a malfunction of the train on track. An emergency may include major disruptions such as a

train on fire requiring passenger evacuation. The TVS control system shall enable the OCC operator to quickly activate the appropriate operation mode of the TVS plant for emergency ventilation of the tunnels or trackway, e.g. to direct smoke away from the evacuation path during fire emergencies.

- To initiate operation of the TVS to provide adequate ventilation in the tunnels during traffic block period (non-revenue period).

5.4..8.3.3 Local Sequential Controller (LSC) by the TVS Contractor shall be provided in the TVS equipment room of each station to maintain the normal operation of the TVS at the station One LSC shall be provided in the TVS room one at each end of the station to control the TVS equipment. Principal functions of the LSCs shall include but not limited to the following:

- To receive commands from the TVS SCADA and perform sequential starting of the equipment with an adjustable pre-set time delays to avoid excessive surge on the power supply system during starting of the equipment.
- To monitor the status and alarm indications of all TVS equipment and provide automatic changeover to the standby or idling equipment whilst retaining flashing indications for the malfunctioned equipment at the Local Controls. The LSCs shall be able to activate or reset buzzers at the associated Local Control Panel upon alarm condition.
- To monitor the status and alarm indications of all TVS and associated equipment and report any change of status to TVS SCADA and the Programming and Maintenance (PM) terminals.
- To perform automatic start-up of the TVS plant in the morning and shut down at night.
- To receive from and send data to TVS SCADA.
- To receive digital status such as the "ON/OFF" or alarm status of equipment.

- To directly control the starting/stopping of the TVS equipment and opening /closing of the associated dampers.
- To output analogue signals in the form of voltage or current (0-10V, 4-20 mA) to the transducers in the control device panel of the equipment where they are converted into suitable signals to drive the actuators or other control device such as valves.
- To receive analogue signals in the form of voltage or current (0-10V, 4-20 mA) from field sensors, convert these signals into Engineering units and reporting them to the TVS SCADA.
- To log and report alarms of analogue signals which have exceeded pre-set high/low or rate of change limits.
- To receive set-point information from the TVS SCADA and PM terminals during initialisation or up dating and store these set-point values in the memory for control reference and function.
- To receive operation mode commands from the TVS SCADA and operate the fans and dampers in a pre-set configuration with insertion of time delays and interlocking logic.
- To monitor the activation of the push buttons or switches on the VCP, and LCP or equivalent commands from the TVS SCADA and execute priority control.
- To automatically restart the TVS equipment when power to TVS plant is restored after a power failure or interruption, sequentially without causing the MCC circuit breakers to trip.
- To provide the interlocking functions required for the TVS and AHU equipment during operation in the TVS Closed System Mode
- To automatically start the standby TVS equipment and their associated equipment and dampers upon detection of failure of the TVS and ECS equipment.

5.4.8.3.4 **Not Used.**

6 Construction and Installation

All works shall be carried out in accordance with this Specification.

6.1 Civil Works

6.1.1 The Contractor shall supply and install all materials including but not limited to brackets, supports and execute all other works needed for supporting and routing all cabling and wiring relating to TVS SCADA. The Civil Structural Contractors will make provisions in structures to accommodate the fastenings of the Contractor. The Contractor shall carry out the necessary interfacing with the civil structural Contractors in respect of the provisions for passage of cables and wiring.

6.1.2 Where cables cross the track or are in any part external to cable trough routes, then they shall be suitably protected. Advantage shall be taken, in consultation with the Civil Structural Contractors, to incorporate such additional protection into the basic construction of the concrete structures. To this end, the Contractor shall establish the necessary liaison within 30 days of award of contract.

6.1.3 Upon completion of cable installation the Contractor shall make good all structural surfaces damaged by his installation and shall in addition seal all openings in accordance with the necessary fire and moisture barrier ratings appropriate for the structure. As a minimum the sealing shall be smoke and vermin proof, made of non-degrading materials and shall not damage the cables or penetrating items either directly or by causing a stress due to expansion and contraction leading to fatigue failure.

6.2 Electrical Works

6.2.1 All cables except main power supply cables, entering or leaving equipment rooms and wayside apparatus boxes shall be terminated in order of their core number on combined terminal/disconnection or terminal/fuse links. Each wire shall be capable of being disconnected and isolated without removing the wire itself. These links shall be easily accessible for inspection and test. Each link or terminal shall be identified with the designation of the circuit it carries.

6.2.2 All electronic equipment shall comply, as a minimum, with IEC 571 or equivalent international specification. All components used shall be purchased from suppliers complying with internationally recognised quality assurance and reliability certification procedures. The Contractor shall declare in his offer the specifications to which he proposes to comply.

6.2.3 Printed circuit boards shall be used to mount electronic components. The boards shall be of sufficient thickness to ensure mechanical rigidity. They shall not be the sole support for connectors, fascia panels, handles etc. Printed edge connectors shall not be used.

6.2.4 All components shall be identified either by carrying a manufacturer's designation or part reference number or unique value in a standard format.

6.2.5 The design of electrical or electronic circuits and units shall be such as to compensate for all likely changes in value parameter during the operational life of the equipment. Any necessity to secure such compensation through adjustable controls shall be declared in the Tender.

6.2.6 Where built-in indicators or meters are provided for maintenance and fault location purposes, then any associated adjustments or controls shall be located such that they can be manipulated and the result observed simultaneously by one person. Built-in indicators shall be provided where frequent observation is required or where portable test equipment is not applicable.

6.2.7 All metal enclosures shall be provided with an earthing terminal. The Contractor shall ensure that all the equipment is properly and adequately earthed in accordance with safety standards.

7 VERIFICATION, TESTING AND COMMISSIONING

7.1 General

7.1.1 The contractor shall perform the stage-wise testing and commissioning activities in accordance with the requirements The contrcator shall carry out testing and commissioning activities in the following phases:

- Factory Acceptance Test
- Installation Test
- Particular Inspection Test
- Site Acceptance Test
- Integrated Testing and Commissioning

7.1.1 In addition to the requirements as laid down in the Gs and the PS , the following particular provisions shall be met with.

7.2 Soak Test

7.2.1 As the initial stage of the FAT and final stage of Contractor’s System Integration Testing, the total system shall be set up in a manner to simulate normal operating conditions, switched on, and allowed to operate continuously.

7.2.2 During the test, measurements and observations shall be made to demonstrate that the equipment fulfils its functional requirement, has adequate stability, and is capable of operating without frequent attention.

(1) Each subsystem and/or each module shall be tested cyclically at least once per hour whilst all other parts are functioning normally.

(2) The test shall run for at least 200 hours continuously. It need not be permanently manned throughout this period provided that a

comprehensive log of operations tested and faults occurring is printed.

(3) Where there is redundancy in the equipment the test period shall be divided equally between the redundant parts. Automatic changeover is not permissible. All modules must remain powered up for the duration of the test.

(4) Test equipment and test software shall be provided to load the equipment to a greater extent than the worst case predicted for the complete system. On-line loading and all functions shall be tested under these worst case conditions. Sufficient hardware (e.g. remote terminals) and/or simulation devices shall be provided by the Contractor to ensure that the Design System Loading conditions can be achieved. The level of System performance proposed to be demonstrated shall be submitted to the Employer's Representative for review.

(5) The tests shall be carried out at the prevailing ambient conditions of temperature and humidity, no special conditioning is required.

7.2.3 If any failures occur, full details shall be recorded for the Employer's Representative. The Contractor shall investigate the cause of all failures and provide evidence that there are no inherent design, or manufacturing faults. The Employer's Representative will then decide whether the test may be restarted or shall be repeated.

7.2.4 The Contractor may propose to the Employer's Representative that this soak test period may be broken down into shorter periods, if compatible with the function of the equipment, and/or less than the whole equipment may be set up or the test may be eliminated completely. The Contractor may proceed with this reduced soak test regime upon receipt of a certificate of no objection from the Employer's Representative.

7.2.5 The final function performed as part of the soak test shall consist of a comprehensive series of measurements and observations of the characteristics and performance of the equipment to demonstrate that no unacceptable deterioration has occurred as a result of previous tests. The equipment shall be tested while supplied at normal supply voltages and subsequently with worst combinations of supply voltages.

7.3 Factory Acceptance Test

7.3.1 The Factory Acceptance Test (FAT) is specified in the GS and the PS. This test may be broken down into two parts.

7.3.2 Subsystem FAT - To prove the design of each Subsystem operationally prior to the Subsystem being used in the System FAT.

7.3.3 A Subsystem FAT shall include the inspection, hardware test and software test of any clearly identifiable Subsystem prior to use as a component in a System test.

7.3.4 System FAT - To check that the totality of the equipment supplied under the Contract performs in accordance with the Contract requirements.

7.3.5 The equipment shall be complete at the start of the tests and no interchange of modules or equipment shall be allowed during the FAT.

7.3.6 All parts subject to wear, such as electromechanical peripherals, may be omitted from the tests if agreed by the Employer's Representative. The printing and recording equipment needed for conducting the test shall be run throughout the test.

7.3.7 No repairs or adjustments shall be carried out during the test period unless agreed by both parties.

7.3.8 Tests shall be conducted to prove the individual and integrated functioning of the system hardware and demonstrate performance in the face of various contingencies.

7.3.9 Integrated system tests shall be conducted to prove the functionality of all applications software in the context of the complete integrated system, equipment and software configuration.

7.3.10 Computer Equipment

(1) The Contractor shall provide all the software necessary to carry out the tests.

(2) Tests shall include:

a) CPU tests.

b) RAM write/read tests.

c) Disc write/read tests.

d) Data highway loading tests.

e) Peripheral tests.

f) Workstation equipment test.

(3) Tests shall exercise communication ports and shall overload ports so that queuing of messages occurs. The tests shall use a simulated network, or where practical, a real network.

7.3.11 Communications

Tests shall include, where appropriate:

(1) Data integrity in the presence of noise.

(2) Loss of Link procedures.

(3) Demonstrate that communication systems do not interfere with each other (e.g. crosstalk) or with other systems.

(4) Demonstration of network management functions.

(5) Programming, control and configuration of the network. The tests shall use a simulated network or, where practical, a real network.

7.3.12 Functional Tests

(1) During the functional tests, every function specified for the system in the Design Specification shall be thoroughly tested. Both positive and negative tests shall be carried out.

(2) Before commencement of the functional tests, all software for which source code is supplied under the Contract shall be reassembled and/or recompiled from source. The resulting object code shall be re-linked and used for the tests.

(3) Similarly, all configurable databases, screen displays and reports shall be regenerated from source. All of these activities shall use compilers, assemblers, linkers and generation/start-up utilities identical to any of those supplied under the Contract.

7.3.13 Performance Tests

(1) System performance tests to demonstrate that the integrated system can achieve the guaranteed levels of response and to determine the limits of the response envelope.

(2) The performance tests shall demonstrate that the performance and response times of the equipment are in accordance with the specified requirements.

7.3.14 Unstructured Tests

In addition to the structured tests described above, all factory acceptance tests shall include a 48 hour period of unstructured testing, during which the Employer's Representative and/or Employer shall be at liberty to instruct the Contractor to carry out such additional tests as may be required to test the reliability and robustness of the system.

7.3.14.1 Remote Terminal Units

(1) For the purposes of FAT and, in particular, system loading tests, the Contractor shall provide at least one RTU of each type

proposed to be installed on the System, for connection to the system under test via an appropriate portion of the communications network associated with the system under test.

(2) The remaining RTUs for the fully extended system may be represented by suitable simulations. However, all simulations must be substantiated to show that they provide a realistic simulation of the associated RTUs and the master server/RTU communication process.

(3) Where there are practical difficulties in obtaining representative RTUs for system FAT, the Contractor shall submit alternative proposals that satisfy the objective of proving the correct functionality and performance.

7.3.14.2 If the Subsystem and System FATs are not immediately consecutive it may be necessary to repeat portions of the Subsystem FAT to confirm that no changes have taken place before the System FAT.

7.3.14.3 It is required that the results of the test shall demonstrate System reliability and availability consistent with the values specified and those guaranteed by the Contractor. The test shall be carried out at the Contractor's premises. Upon satisfactory completion of the test, the System will be ready for delivery to site.

APPENDIX-L

INTERFACE MANAGEMENT DOCUMENT FOR CIVIL, TUNNEL, VENTILLATION, ECS, E&M, POWER SUPPLY, S&T, AFC, ESCALATORS, LIFTS AND TRACK CONTRATS OF UNDERGROUND

This document describes the interface responsibilities and obligations of civil contractor with other system contractors like Tunnel Ventilation, ECS, E&M, Power Supply, S&T, AFC, Escalators, Lifts and Track and vice versa. This document shall be made part of all these contracts so that clear responsibility of each contractor is defined in every contract. This document is for underground works only.

1. ATTENDANCE ON OTHER CONTRACTORS

(I) **Work Areas-** Civil to provide property leveled and debris free site storage space and works areas, access to and within the site, offloading and lowering areas for the use of all contractors. System contractors to advise requirements and date for handover to suit civil contractor's site program.

(II) **Cranes-** Civil to permit use of cranes on site by other contractors on a mutually agreed rental basis.

(III) **Scaffold-** Civil to permit other contractors the use of scaffolding erected at site but only to the timings advised by the civil contractor.

(IV) **Medical-** Civil to provide a first aid room at each station and the servies of a staff trained in First Aid. This will be for use by other system contractors also.

(V) **Water-** Civil to provide drinking water facilities and water supply points for the works at each end of the concourse and platform for the use of all contractors if they wish to use and may change at mutually agreed rates.

(VI) **Lighting-** Civil to provide general lighting to all areas and all rooms of the stations and tunnels required for a safe working environment as per lighting levels mentioned in SHE with uniformly distributed tube lights (Not by mere halogen lamps) is maintained at all times till permanent lighting becomes functional or ROD whichever is earlier. However, any shifting of light fittings provided by civil required by system contractor will be done by system contractor at his cost only.

(VII) **Power-** Civil to supply power distribution boards at each end of the concourse and platform and at 150m intervals along the tunnel length for the use of all contractors power capacity to suit the combined requirements of each contractor. The charge rate per unit of consumption is to be agreed with the system contractors. The power supply shall be maintained until 1 month after energization of the LV system at ASS level or the confirmation from the system contractor whichever is earlier.

(VIII) **Survey-** Civil to provide survey/setting out grid line and level references with in stations and tunnels.

(IX) **Cleaning-**Civil will be responsible for general site cleaning an d will identity common areas at each level for material to be deposited prior to removal Large items such as cable drums/heavy packing shall be cleared by the respective system contractors In case any system contractor fails to remove his material, the Engineer of Civil Contract after written notice of minimum one day to the system contractor remove his material, may instruct civil contractor to remove it and the cost of the same shall be borne by the system contractor. The decision of the Engineer of civil contractor shll be final and binding on civil as well as on the system contractor. Civil will hand over the rooms to respective system contractors in property cleaner condition and after providing proper lockable door without gap. Once technical room is handed over, the principal system contractor for that room will take over responsibility for cleaning the room.

(X) **Security-** Civil will be responsible for establishing a site security system to the approval of the Engineer. The system should ensure that no labour from any agency working at site may remove materials without written authorization from the civil security-in-charge. The system one approved by the Engineer of civil contract shall be binding on all system contracts.

(XI) **Safety-** Civil will be in overall charge of safety and will advise JMRC staff of and safety violation by system contractors requiring corrective action.

(XII) **Toilet-** Civil shall provide at his own cost adequate toilet facilities at ground level each station and 4 Nos of urinals at platform and 4 Nos. at concourse level at each station with adequate storage and pumping facilities to ensure hygienic conditions all times. These facilities shall be used by staff and labour of all system contractors also for which they shall pay only maintenance and running charges for usage mutually agreed rates. In case of disagreement in usage charges, the decision of Engineer of civil contractor shall be final and binding on civil as well as system contractors.

(XIII) **Drainage-** Civil contractor to provide and maintain temporary pumping arrangements until ROD or commissioning of permanent pumps whichever are earlier Civil and E&M contractors will coordinate to install permanent pumps such the drainage of the sup is not interrupted.

2. GENERAL INTERFACE REQUIREMENTS

(I) Civil to provide opening as per SEM drawings or Combined Services Drawing (CSD). Any change requested by system contractor in writing with the approval the Engineer of his contract before the work of opening is taken up by civil shall incorporated by civil. Any change in the opening size whether increase or reduction after this shall be the responsibility of the system contractor and he will do the sealing around the services including masonary/concrete work if required at cost.

Dimensions, locations, support details, interface with wall and veiling finishes acoustic requirements (if any)

(II) Civil to provide cutouts and recesses in slabs and walls for the passage of services as per the SEM drawings. Changes to the cutouts required after casting or block wall construction shall be to the account of the agency responsible for the change.

(III) Civil to design and build equipment foundations, Loads and other details are the given by respective contractor at least 90 days before these are required by him.

(IV) Change to any provisions with in the civil scope of work after completion, such as services opening, lifting/pulling hooks foundations, ducts, CE shall be to the account of the agency responsible for the change.

(V) Civil to prepare equipment delivery plans for major materials and plant of the system contractors showing temporary and permanent provisions in slabs and walls to permit future replacement of plant and to allow initial transport from ground level to final room location.

3. INTERFACE WITH INDIVIDUAL CONTRACTORS

A. CIVIL WITH TUNNEL VENT

(i) TVS contractor to supply the details of all loads, plant layouts equipment foundation for room sizes, knockout panels cutouts, recesses, shaft/gallery sizes and tunnel niche dimensions. Changes required to details incorporated in approved drawings to be provided well in advance of casting.

(ii) Civil to design and build rooms, room finishes, drainage, shaft, precast RCC slabs for covering the access hatch, galleries, cutouts, lifting/pulling hooks, walls for nozzles, niches in c&c tunnel roof, trackside knockout panels. Chequer plate infill around nozzles will be provided by the TVS contractor.

B. CIVIL WITH ECS

(i) ECS contractor to supply details of all loads, plant layouts, equipment foundations, room drainage requirements room sizes, pipe support pedestals, lowering hatches, cutouts, recesses, shaft/gallery sizes.

(ii) Civil to design and build rooms, room finishes, drainage, equipment foundations, pipe pedestals, shafts, cutouts, lifting/pulling hooks, canopy/slabs to cover access hatch as per drawing.

(iii) Civil to design and build architectural finishes in public areas with provision for ecs fixtures including cutouts in architectural finishes for passage of services and installation of fixtures.

C. CIVIL WITH E&M

(i) E&M contractor to supply details of all loads, plant layouts, equipment foundation room drainage requirements, room sizes, cutouts, recesses, cable gallery sizes, LV earthmat and earthing terminations.

(ii) Civil to design and build rooms, room finishes, drainage, equipment foundation shafts/galleries, cutouts & recesses in stations & tunnel cross passage lifting/pulling hooks earthmat, earthing risers through base slab to slab to earthing terminations.

(iii) E&M contractor to provide chequer plate/fire rated infill where openings in floot exceed the dimensions of the LV equipment.

(iv) Civil to design and build architectural finishes in public areas with provision for e&m fixtures including cutouts & provisions in architectural finishes for passage services and installation of fixtures.

D. CIVIL WITH POWER SUPPLY (ASS & ROCS)

(i) Power supply contractor to supply details of all loads, plant layouts, equipment foundations, room sizes (ASS, UPS, Sectioning room) cutouts, recesses cable gallery/shaft sizes cable ducts within slabs, lifting/pulling hooks, HV earthmat and earthing terminations.

(ii) Power supply contractor to make good any unused OCS bracket drill holes in the tunnel roof.

(iii) Civil to design and build rooms, knockout panels, room finishes, equipment foundations, shafts/galleries, cutouts, recesses, cable ducts within slab lifting/pulling hooks, earthmat, earthing risers through base slab to earthing terminations.

(iv) Power supply contractor to provide chequer plate/fire rated infill where opening floors or walls exceed the dimension of the HT equipment or due to any other reason.

(v) Civil to mark center line of track on the soffit of the tunnel.

E. <u>CIVIL WITH S&T</u>

(i) S&T contractors to supply details of all loads equipment layouts equipment foundations, room size & finishes details (SER, SMR, SCR, TER, UPS, mobile phone operators room), cutouts, recesses cable ducts within slabs, cable shafts clean earthmat and earthing terminations.

(ii) S&T contractors to supply details of equipment located in station public area in dimensions, locations support details interface with wall and ceiling finished acoustic requirements (if any).

(iii) Civil to design and build rooms, room finishes, equipment foundations, shafts/galleries, cutouts 7 recesses in stations and at tunnel cross passages, cable ducts within slabs, clean earthmat, earthing risers through base slab to earthing terminations. Civil to provide trenches in UPS room as per the drawings given by UPS contractor and shall provide trench covers with the required openings in the covers.

(iv) Civil to design and build architectural finishes in public areas with provision for coms fixtures including cutouts & provisions in architectural finishes for passage of services and installation of fixtures.

(v) Signaling contractors to provide false floor in SER Telecom contractor to provide false floor in TER. Civil to provide false floor in SCR and TOM.

F. <u>CIVIL WITH AFC</u>

(i) AFC contractor to supply details of all equipment layouts, equipment foundations, room sizes & finishes details (TOMS, EFO,SCR), cutouts recesses, cable ducts within slabs/screed.

(ii) AFC contractor to supply details of fare gates and barriers located in station public area in dimensions, locations, support details & interface with floor finishes. The barriers will be provided by the AFC contractor to close the entire gap upto wall.

(iii) Civil to design and build rooms, room finishes, equipment foundations, cutouts & recesses, cable ducts within slabs, architectural finishes in public areas with provision for fare gates & barriers.

G. <u>CIVIL WITH ESCALATORS</u>

(i) Escalator contractor to supply shafts & pit dimensional data, and intermediate support details, earthing requirement, equipment loads cutout & recess details, lifting hook locations & details, services routes, delivery route and method of erection, ecp recess dimensions, SCR equipment layout.

(ii) Civil contractor to design and build escalator shaft with top and bottom supports, finishes meeting the escalator requirements at top/bottom and sides of escalator lifting hooks, pit, drainage and provision for cable and sides of escalator lifting hooks, pit, drainage and provision for cable and sprinkler pipe routing, ecp recess SCR layout and earthing terminals.

H. <u>CIVIL WITH LIFTS</u>

(i) Lift contractor to supply shaft dimensional data and details of cutouts, recesses, lifting beams, drainage, and provision for surface mounted fixtures.

(ii) Civil contractor to design and build lift shaft with cutouts recesses, provision for lifting beams, drainage rain shelter as per drawing and internal shaft plaster & plant finish.

I. <u>CIVIL WITH TRACKWORK</u>

(i) Civil to provide openings for rail lowering at least at every ultimate station or at alternate locations such that maximum hauling of rails is 2 Kms. The openings should be 20 m in length and 5 m in width unless agreed otherwise with the track work contractor. An area for rail storage at ground level and an access route from the public road thereto are to be provided by the civil contractor.

(ii) The timing for closure of these openings is to be agreed with the track work contractor and approved by the Engineer.

(iii) Track contractor to provide details for drainage of the track to the tunnel cross passage sumps and to station trackside drains.

(iv) Civil and track work contractors to jointly inspect the tunnels and station track areas before track concreting commences. The track work contractor is to hand over the tunnels after completing his work in the same condition as recorded in the joint survey.

(v) The track work contractor will be responsible for disposal of waste water resulting from his works such that the tunnels are maintained in an environmentally acceptable condition at all times.

END OF APPENDIX

S.No	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	SIGNAL TYPE			
				AI	AO	DI	DO
	From DB-140						
	MDB-140 Incoming Breaker						
1	ATS/PLC Auto/Manual Status	Soft Link	Soft Link			DI	
2	Primary Breaker Trip status	Soft Link	Soft Link			DI	
3	Primary Breaker Open status	Soft Link	Soft Link			DI	
4	Primary Breaker Close status	Soft Link	Soft Link			DI	
5	Secondary Breaker Trip Status	Soft Link	Soft Link			DI	
6	Secondary Breaker Open Status	Soft Link	Soft Link			DI	
7	Secondary Breaker Close Status	Soft Link	Soft Link			DI	
8	Incoming Feeder Line Voltage	Soft Link	Soft Link	AI			
9	Incoming Feeder Line Current	Soft Link	Soft Link	AI			
10	Incoming Feeder Volt Ampere (VA)	Soft Link	Soft Link	AI			
11	Incoming Feeder Frequency (Hz)	Soft Link	Soft Link	AI			
12	Incoming Feeder Power Factor (PF)	Soft Link	Soft Link	AI			
13	Incoming Feeder Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
14	Incoming Feeder Volt Ampere Reactive (VAR)	Soft Link	Soft Link	AI			
15	Dual Supply Status	VFC	24 VDC			1	
16	Main supply off alarm	VFC	24 VDC			1	
17	~~Incoming Feeder Protection Relay Operation Status~~						
18	~~DB-140 Local Remote Status~~						
	TUNNEL VENTILATION FAN (TVF-201)						
1	Tunnel Ventilation Fan Local / Remote Switch Status	VFC	24 VDC			1	
2	Tunnel Ventilation Fan Forward ON / OFF Command	230 VAC	VFC				1
3	Tunnel Ventilation Fan Reverse ON / OFF Command	230 VAC	VFC				1
4	Tunnel Ventilation Fan Forward Run status	VFC	24 VDC			1	
5	Tunnel Ventilation Fan Reverse Run status	VFC	24 VDC			1	
6	Tunnel Ventilation Fan Emergency Stop Button Position	VFC	24 VDC			1	
7	Tunnel Ventilation Fan Motor Trip	VFC	24 VDC			1	
8	Tunnel Ventilation Fan FID Close status	VFC	24 VDC			1	
9	Tunnel Ventilation Fan FID Open status	VFC	24 VDC			1	
10	Tunnel Ventilation Fan Motor Current	4-20 mA	4-20 mA	1			
11	Tunnel Ventilation Fan Vibration Sensor	4-20 mA	4-20 mA	1			
12	Tunnel Ventilation Fan Forward Air Flow status	VFC	24 VDC			1	
13	Tunnel Ventilation Fan Reverse Air Flow status	VFC	24 VDC			1	
14	Tunnel Ventilation Fan Winding Thermal over load Alarm	VFC	24 VDC			1	
15	Tunnel Ventilation Fan Group Bypass Command	230 VAC	VFC				1
16	Tunnel Ventilation Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
17	No of start	Soft Link	Soft Link	AI			
18	Running Hours	Soft Link	Soft Link	AI			
19	~~Tunnel Vendilation Fan Sppedswith Alarm~~	~~VFC~~	~~24 VDC~~				
	TUNNEL VENTILATION FAN (TVF-202)						
1	Tunnel Ventilation Fan Local / Remote Switch Status	VFC	24 VDC			1	
2	Tunnel Ventilation Fan Forward ON / OFF Command	230 VAC	VFC				1
3	Tunnel Ventilation Fan Reverse ON / OFF Command	230 VAC	VFC				1
4	Tunnel Ventilation Fan Forward Run status	VFC	24 VDC			1	
5	Tunnel Ventilation Fan Reverse Run status	VFC	24 VDC			1	
6	Tunnel Ventilation Fan Emergency Stop Button Position	VFC	24 VDC			1	
7	Tunnel Ventilation Fan Motor Trip	VFC	24 VDC			1	
8	Tunnel Ventilation Fan FID Close status	VFC	24 VDC			1	
9	Tunnel Ventilation Fan FID Open status	VFC	24 VDC			1	
10	Tunnel Ventilation Fan Motor Current	4-20 mA	4-20 mA	1			
11	Tunnel Ventilation Fan Vibration Sensor	4-20 mA	4-20 mA	1			
12	Tunnel Ventilation Fan Forward Air Flow status	VFC	24 VDC			1	
13	Tunnel Ventilation Fan Reverse Air Flow status	VFC	24 VDC			1	
14	Tunnel Ventilation Fan Winding Thermal over load Alarm	VFC	24 VDC			1	
15	Tunnel Ventilation Fan Group Bypass Command	230 VAC	VFC				1
16	Tunnel Ventilation Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
17	No of start	Soft Link	Soft Link	AI			
18	Running Hours	Soft Link	Soft Link	AI			
19	~~Tunnel Vendilation Fan Sppedswith Alarm~~	~~VFC~~	~~24 VDC~~				

S.No	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	SIGNAL TYPE			
				AI	AO	DI	DO
	RETURN DAMPER (TVD-201)						
1	Damper Local/Remote Switch Status	VFC	24 VDC			1	
2	Damper Open Position	VFC	24 VDC			1	
3	Damper Close Position	VFC	24 VDC			1	
4	Damper Trip Status	VFC	24 VDC			1	
5	Damper Open/Close Command	230 VAC	VFC				1
	RETURN DAMPER (TVD-202)						
1	Damper Local/Remote Switch Status	VFC	24 VDC			1	
2	Damper Open Position	VFC	24 VDC			1	
3	Damper Close Position	VFC	24 VDC			1	
4	Damper Trip Status	VFC	24 VDC			1	
5	Damper Open/Close Command	230 VAC	VFC				1
	DRAFT RELIEF DAMPER (DRD-201)						
1	Damper Local/Remote Switch Status	VFC	24 VDC			1	
2	Damper Open Position	VFC	24 VDC			1	
3	Damper Close Position	VFC	24 VDC			1	
4	Damper Trip Status	VFC	24 VDC			1	
5	Damper Open/Close Command	230 VAC	VFC				1
	DRAFT RELIEF DAMPER (DRD-202)						
1	Damper Local/Remote Switch Status	VFC	24 VDC			1	
2	Damper Open Position	VFC	24 VDC			1	
3	Damper Close Position	VFC	24 VDC			1	
4	Damper Trip Status	VFC	24 VDC			1	
5	Damper Open/Close Command	230 VAC	VFC				1
	NOZZLE DAMPER (NZD-201)						
1	DAMPER Local/Remote Switch Status	VFC	24 VDC			1	
2	DAMPER Open Position	VFC	24 VDC			1	
3	DAMPER Close Position	VFC	24 VDC			1	
4	Damper Trip Status	VFC	24 VDC			1	
5	DAMPER Open/Close Command	230 VAC	VFC				1
	NOZZLE DAMPER (NZD-202)						
1	DAMPER Local/Remote Switch Status	VFC	24 VDC			1	
2	DAMPER Open Position	VFC	24 VDC			1	
3	DAMPER Close Position	VFC	24 VDC			1	
4	Damper Trip Status	VFC	24 VDC			1	
5	DAMPER Open/Close Command	230 VAC	VFC				1
	ENVIRONMENT DRAFT RELIEF DAMPER (ETVD-301)						
1	Damper Local/Remote Switch Status	VFC	24 VDC			1	
2	Damper Open Position	VFC	24 VDC			1	
3	Damper Close Position	VFC	24 VDC			1	
4	Damper Trip Status	VFC	24 VDC			1	
5	Damper Open/Close Command	230 VAC	VFC				1
	EXHAUST SHAFT DAMPER (SD-301)						
1	Damper Local/Remote Switch Status	VFC	24 VDC			1	
2	Damper Open Position	VFC	24 VDC			1	
3	Damper Close Position	VFC	24 VDC			1	
4	Damper Trip Status	VFC	24 VDC			1	
5	Damper Open/Close Command	230 VAC	VFC				1
	SPARE DAMPER (SPARE-TVD)						
1	Damper Local/Remote Switch Status	VFC	24 VDC			1	
2	Damper Open Position	VFC	24 VDC			1	
3	Damper Close Position	VFC	24 VDC			1	
4	Damper Trip Status	VFC	24 VDC			1	
5	Damper Open/Close Command	230 VAC	VFC				1
	FROM DB-130						
	TRACKWAY EXHAUST FAN (TEF-301)						
1	Trackway Exhaust Fan Local / Remote Switch Status	VFC	24 VDC			1	
2	Trackway Exhaust Fan ON / OFF Command	230 VAC	VFC				1
3	Trackway Exhaust Fan Run status	VFC	24 VDC			1	
4	Trackway Exhaust Fan Emergency Stop Button Position	VFC	24 VDC			1	
5	Trackway Exhaust Fan Motor Trip	VFC	24 VDC			1	

S.No	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	SIGNAL TYPE AI	AO	DI	DO
6	Trackway Exhaust Fan FID Close status	VFC	24 VDC			1	
7	Trackway Exhaust Fan FID Open status	VFC	24 VDC			1	
8	Trackway Exhaust Fan Air Flow status	VFC	24 VDC			1	
9	Trackway Exhaust Fan Motor Current	4-20 mA	4-20 mA	1			
10	Trackway Exhaust Fan Vibration Sensor	4-20 mA	4-20 mA	1			
11	Trackway Exhaust Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
12	Trackway Exhaust Fan Winding Thermal over load Alarm	4-20 mA	4-20 mA	1			
13	Trackway Exhaust Fan Group Bypass Command	230 VAC	VFC				1
14	~~Trackway Exhaust Fan SpeedSwitch Alarm~~	~~VFC~~	~~24 VDC~~				
	TRACKWAY EXHAUST FAN (TEF-302)						
1	Trackway Exhaust Fan Local / Remote Switch Status	VFC	24 VDC			1	
2	Trackway Exhaust Fan ON / OFF Command	230 VAC	VFC				1
3	Trackway Exhaust Fan Run status	VFC	24 VDC			1	
4	Trackway Exhaust Fan Emergency Stop Button Position	VFC	24 VDC			1	
5	Trackway Exhaust Fan Motor Trip	VFC	24 VDC			1	
6	Trackway Exhaust Fan FID Close status	VFC	24 VDC			1	
7	Trackway Exhaust Fan FID Open status	VFC	24 VDC			1	
8	Trackway Exhaust Fan Air Flow status	VFC	24 VDC			1	
9	Trackway Exhaust Fan Motor Current	4-20 mA	4-20 mA	1			
10	Trackway Exhaust Fan Vibration Sensor	4-20 mA	4-20 mA	1			
11	Trackway Exhaust Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
12	Trackway Exhaust Fan Winding Thermal over load Alarm	4-20 mA	4-20 mA	1			
13	Trackway Exhaust Fan Group Bypass Command	230 VAC	VFC				1
14	~~Trackway Exhaust Fan SpeedSwitch Alarm~~	~~VFC~~	~~24 VDC~~				
	TRACKWAY EXHAUST FAN (TEF-303)						
1	Trackway Exhaust Fan Local / Remote Switch Status	VFC	24 VDC			1	
2	Trackway Exhaust Fan ON / OFF Command	230 VAC	VFC				1
3	Trackway Exhaust Fan Run status	VFC	24 VDC			1	
4	Trackway Exhaust Fan Emergency Stop Button Position	VFC	24 VDC			1	
5	Trackway Exhaust Fan Motor Trip	VFC	24 VDC			1	
6	Trackway Exhaust Fan FID Close status	VFC	24 VDC			1	
7	Trackway Exhaust Fan FID Open status	VFC	24 VDC			1	
8	Trackway Exhaust Fan Air Flow status	VFC	24 VDC			1	
9	Trackway Exhaust Fan Motor Current	4-20 mA	4-20 mA	1			
10	Trackway Exhaust Fan Vibration Sensor	4-20 mA	4-20 mA	1			
11	Trackway Exhaust Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
12	Trackway Exhaust Fan Winding Thermal over load Alarm	4-20 mA	4-20 mA	1			
13	Trackway Exhaust Fan Group Bypass Command	230 VAC	VFC				1
14	~~Trackway Exhaust Fan SpeedSwitch Alarm~~	~~VFC~~	~~24 VDC~~				
	SPARE TRACKWAY EXHAUST FAN (SPARE-TEF)						
1	Trackway Exhaust Fan Local / Remote Switch Status	VFC	24 VDC			1	
2	Trackway Exhaust Fan ON / OFF Command	230 VAC	VFC				1
3	Trackway Exhaust Fan Run status	VFC	24 VDC			1	
4	Trackway Exhaust Fan Emergency Stop Button Position	VFC	24 VDC			1	
5	Trackway Exhaust Fan Motor Trip	VFC	24 VDC			1	
6	Trackway Exhaust Fan FID Close status	VFC	24 VDC			1	
7	Trackway Exhaust Fan FID Open status	VFC	24 VDC			1	
8	Trackway Exhaust Fan Motor Current	4-20 mA	4-20 mA	1			
9	Trackway Exhaust Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
10	Trackway Exhaust Fan Group Bypass Command	230 VAC	VFC				1
11	~~Trackway Exhaust Fan SpeedSwitch Alarm~~	~~VFC~~	~~24 VDC~~				
	SMOKE EXHAUST FAN (SEF-301)						
1	Somke Exhaust Fan Local / Remote Switch Status	VFC	24 VDC			1	
2	Somke Exhaust Fan ON / OFF Command	230 VAC	VFC				1
3	Somke Exhaust Fan Run status	VFC	24 VDC			1	
4	Somke Exhaust Fan Emergency Stop Button Position	VFC	24 VDC			1	
5	Somke Exhaust Fan Motor Trip	VFC	24 VDC			1	
6	Somke Exhaust Fan FID Close status	VFC	24 VDC			1	
7	Somke Exhaust Fan FID Open status	VFC	24 VDC			1	
8	Somke Exhaust Fan Air Flow status	VFC	24 VDC			1	

S.No	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	SIGNAL TYPE AI	AO	DI	DO
9	Somke Exhaust Fan Motor Current	4-20 mA	4-20 mA	1			
10	Somke Exhaust FAN Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
11	Somke Exhaust Fan GroupByPass Command	230 VAC	VFC				1
	SMOKE EXHAUST FAN (SEF-302)						
1	Somke Exhaust Fan Local / Remote Switch Status	VFC	24 VDC			1	
2	Somke Exhaust Fan ON / OFF Command	230 VAC	VFC				1
3	Somke Exhaust Fan Run status	VFC	24 VDC			1	
4	Somke Exhaust Fan Emergency Stop Button Position	VFC	24 VDC			1	
5	Somke Exhaust Fan Motor Trip	VFC	24 VDC			1	
6	Somke Exhaust Fan FID Close status	VFC	24 VDC			1	
7	Somke Exhaust Fan FID Open status	VFC	24 VDC			1	
8	Somke Exhaust Fan Air Flow status	VFC	24 VDC			1	
9	Somke Exhaust Fan Motor Current	4-20 mA	4-20 mA	1			
10	Somke Exhaust FAN Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
11	Somke Exhaust Fan GroupByPass Command	230 VAC	VFC				1
	SPARE SMOKE EXHAUST FAN (SPARE-SEF)						
1	Somke Exhaust Fan Local / Remote Switch Status	VFC	24 VDC			1	
2	Somke Exhaust Fan ON / OFF Command	230 VAC	VFC				1
3	Somke Exhaust Fan Run status	VFC	24 VDC			1	
4	Somke Exhaust Fan Emergency Stop Button Position	VFC	24 VDC			1	
5	Somke Exhaust Fan Motor Trip	VFC	24 VDC			1	
6	Somke Exhaust Fan FID Close status	VFC	24 VDC			1	
7	Somke Exhaust Fan FID Open status	VFC	24 VDC			1	
8	Somke Exhaust Fan Motor Current	4-20 mA	4-20 mA	1			
9	Somke Exhaust FAN Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
10	Somke Exhaust Fan GroupByPass Command	230 VAC	VFC				1
	STAIRCASE PRESSURIZATION FAN (SPF-301)						
1	STAIRCASE PRESSURIZATION FAN Local / Remote Switch Status	VFC	24 VDC			1	
2	STAIRCASE PRESSURIZATION FAN ON / OFF Command	230 VAC	VFC				1
3	STAIRCASE PRESSURIZATION FAN Run status	VFC	24 VDC			1	
4	STAIRCASE PRESSURIZATION FAN Emergency Stop Button Position	VFC	24 VDC			1	
5	STAIRCASE PRESSURIZATION FAN FID Close status	VFC	24 VDC			1	
6	STAIRCASE PRESSURIZATION FAN FID Open status	VFC	24 VDC			1	
7	STAIRCASE PRESSURIZATION FAN Motor Current	4-20 mA	4-20 mA	1			
8	STAIRCASE PRESSURIZATION FAN Motor Trip	VFC	24 VDC			1	
9	STAIRCASE PRESSURIZATION FAN Air Flow status	VFC	24 VDC			1	
10	STAIRCASE PRESSURIZATION FAN Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
11	STAIRCASE PRESSURIZATION FAN GroupByPass Command	230 VAC	VFC				1
	STAIRCASE PRESSURIZATION FAN (SPF-401)						
1	STAIRCASE PRESSURIZATION FAN Local / Remote Switch Status	VFC	24 VDC			1	
2	STAIRCASE PRESSURIZATION FAN ON / OFF Command	230 VAC	VFC				1
3	STAIRCASE PRESSURIZATION FAN Run status	VFC	24 VDC			1	
4	STAIRCASE PRESSURIZATION FAN Emergency Stop Button Position	VFC	24 VDC			1	
5	STAIRCASE PRESSURIZATION FAN FID Close status	VFC	24 VDC			1	
6	STAIRCASE PRESSURIZATION FAN FID Open status	VFC	24 VDC			1	
7	STAIRCASE PRESSURIZATION FAN Motor Current	4-20 mA	4-20 mA	1			
8	STAIRCASE PRESSURIZATION FAN Motor Trip	VFC	24 VDC			1	
9	STAIRCASE PRESSURIZATION FAN Air Flow status	VFC	24 VDC			1	
10	STAIRCASE PRESSURIZATION FAN Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
11	STAIRCASE PRESSURIZATION FAN GroupByPass Command	230 VAC	VFC				1
	STAIRCASE PRESSURIZATION FAN (SPF-402)						
1	STAIRCASE PRESSURIZATION FAN Local / Remote Switch Status	VFC	24 VDC			1	
2	STAIRCASE PRESSURIZATION FAN ON / OFF Command	230 VAC	VFC				1
3	STAIRCASE PRESSURIZATION FAN Run status	VFC	24 VDC			1	
4	STAIRCASE PRESSURIZATION FAN Emergency Stop Button Position	VFC	24 VDC			1	
5	STAIRCASE PRESSURIZATION FAN FID Close status	VFC	24 VDC			1	
6	STAIRCASE PRESSURIZATION FAN FID Open status	VFC	24 VDC			1	
7	STAIRCASE PRESSURIZATION FAN Motor Current	4-20 mA	4-20 mA	1			
8	STAIRCASE PRESSURIZATION FAN Motor Trip	VFC	24 VDC			1	
9	STAIRCASE PRESSURIZATION FAN Air Flow status	VFC	24 VDC			1	

S.No	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	SIGNAL TYPE			
				AI	AO	DI	DO
10	STAIRCASE PRESSURIZATION FAN Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
11	STAIRCASE PRESSURIZATION FAN GroupByPass Command	230 VAC	VFC				1
	STAIRCASE PRESSURIZATION FAN (SPF-303)						
1	STAIRCASE PRESSURIZATION FAN Local / Remote Switch Status	VFC	24 VDC			1	
2	STAIRCASE PRESSURIZATION FAN ON / OFF Command	230 VAC	VFC				1
3	STAIRCASE PRESSURIZATION FAN Run status	VFC	24 VDC			1	
4	STAIRCASE PRESSURIZATION FAN Emergency Stop Button Position	VFC	24 VDC			1	
5	STAIRCASE PRESSURIZATION FAN FID Close status	VFC	24 VDC			1	
6	STAIRCASE PRESSURIZATION FAN FID Open status	VFC	24 VDC			1	
7	STAIRCASE PRESSURIZATION FAN Motor Current	4-20 mA	4-20 mA	1			
8	STAIRCASE PRESSURIZATION FAN Motor Trip	VFC	24 VDC			1	
9	STAIRCASE PRESSURIZATION FAN Air Flow status	VFC	24 VDC			1	
10	STAIRCASE PRESSURIZATION FAN Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
11	STAIRCASE PRESSURIZATION FAN GroupByPass Command	230 VAC	VFC				1
	Tunnel Booster Fan (TBF-301)						
1	Tunnel Booster Fan Local / Remote Switch Status	VFC	24 VDC			1	
2	Tunnel Booster Fan Forward ON / OFF Command	230 VAC	VFC				1
3	Tunnel Booster Fan Reverse ON / OFF Command	230 VAC	VFC				1
4	Tunnel Booster Fan Forward Run status	VFC	24 VDC			1	
5	Tunnel Booster Fan Reverse Run status	VFC	24 VDC			1	
6	Tunnel Booster Fan Emergency Stop Button Position	VFC	24 VDC			1	
7	Tunnel Booster Fan Motor Trip	VFC	24 VDC			1	
8	Tunnel Booster Fan Motor Current	4-20 mA	4-20 mA	1			
9	Tunnel Booster Fan Vibration Sensor	4-20 mA	4-20 mA	1			
10	Tunnel Booster Fan Forward Air Flow status	VFC	24 VDC			1	
11	Tunnel Booster Fan Reverse Air Flow status	VFC	24 VDC			1	
12	Tunnel Booster Fan Winding Thermal over load Alarm	VFC	24 VDC			1	
13	Tunnel Booster Fan Group Bypass Command	230 VAC	VFC				1
14	Tunnel Booster Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
15	No of start	Soft Link	Soft Link	AI			
16	Running Hours	Soft Link	Soft Link	AI			
17	~~Tunnel Booster Fan Sppedswith Alarm~~	~~VFC~~	~~24 VDC~~				
	Tunnel Booster Fan (TBF-302)						
1	Tunnel Booster Fan Local / Remote Switch Status	VFC	24 VDC			1	
2	Tunnel Booster Fan Forward ON / OFF Command	230 VAC	VFC				1
3	Tunnel Booster Fan Reverse ON / OFF Command	230 VAC	VFC				1
4	Tunnel Booster Fan Forward Run status	VFC	24 VDC			1	
5	Tunnel Booster Fan Reverse Run status	VFC	24 VDC			1	
6	Tunnel Booster Fan Emergency Stop Button Position	VFC	24 VDC			1	
7	Tunnel Booster Fan Motor Trip	VFC	24 VDC			1	
8	Tunnel Booster Fan Motor Current	4-20 mA	4-20 mA	1			
9	Tunnel Booster Fan Vibration Sensor	4-20 mA	4-20 mA	1			
10	Tunnel Booster Fan Forward Air Flow status	VFC	24 VDC			1	
11	Tunnel Booster Fan Reverse Air Flow status	VFC	24 VDC			1	
12	Tunnel Booster Fan Winding Thermal over load Alarm	VFC	24 VDC			1	
13	Tunnel Booster Fan Group Bypass Command	230 VAC	VFC				1
14	Tunnel Booster Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
15	No of start	Soft Link	Soft Link	AI			
16	Running Hours	Soft Link	Soft Link	AI			
17	~~Tunnel Booster Fan Sppedswith Alarm~~	~~VFC~~	~~24 VDC~~				
	Tunnel Booster Fan (TBF-303)						
1	Tunnel Booster Fan Local / Remote Switch Status	VFC	24 VDC			1	
2	Tunnel Booster Fan Forward ON / OFF Command	230 VAC	VFC				1
3	Tunnel Booster Fan Reverse ON / OFF Command	230 VAC	VFC				1
4	Tunnel Booster Fan Forward Run status	VFC	24 VDC			1	
5	Tunnel Booster Fan Reverse Run status	VFC	24 VDC			1	
6	Tunnel Booster Fan Emergency Stop Button Position	VFC	24 VDC			1	
7	Tunnel Booster Fan Motor Trip	VFC	24 VDC			1	
8	Tunnel Booster Fan Motor Current	4-20 mA	4-20 mA	1			
9	Tunnel Booster Fan Vibration Sensor	4-20 mA	4-20 mA	1			

S.No	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	SIGNAL TYPE			
				AI	AO	DI	DO
10	Tunnel Booster Fan Forward Air Flow status	VFC	24 VDC			1	
11	Tunnel Booster Fan Reverse Air Flow status	VFC	24 VDC			1	
12	Tunnel Booster Fan Winding Thermal over load Alarm	VFC	24 VDC			1	
13	Tunnel Booster Fan Group Bypass Command	230 VAC	VFC				1
14	Tunnel Booster Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
15	No of start	Soft Link	Soft Link	AI			
16	Running Hours	Soft Link	Soft Link	AI			
17	~~Tunnel Booster Fan Sppedswith Alarm~~	~~VFC~~	~~24 VDC~~				
	Tunnel Booster Fan (TBF-304)						
1	Tunnel Booster Fan Local / Remote Switch Status	VFC	24 VDC			1	
2	Tunnel Booster Fan Forward ON / OFF Command	230 VAC	VFC				1
3	Tunnel Booster Fan Reverse ON / OFF Command	230 VAC	VFC				1
4	Tunnel Booster Fan Forward Run status	VFC	24 VDC			1	
5	Tunnel Booster Fan Reverse Run status	VFC	24 VDC			1	
6	Tunnel Booster Fan Emergency Stop Button Position	VFC	24 VDC			1	
7	Tunnel Booster Fan Motor Trip	VFC	24 VDC			1	
8	Tunnel Booster Fan Motor Current	4-20 mA	4-20 mA	1			
9	Tunnel Booster Fan Vibration Sensor	4-20 mA	4-20 mA	1			
10	Tunnel Booster Fan Forward Air Flow status	VFC	24 VDC			1	
11	Tunnel Booster Fan Reverse Air Flow status	VFC	24 VDC			1	
12	Tunnel Booster Fan Winding Thermal over load Alarm	VFC	24 VDC			1	
13	Tunnel Booster Fan Group Bypass Command	230 VAC	VFC				1
14	Tunnel Booster Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
15	No of start	Soft Link	Soft Link	AI			
16	Running Hours	Soft Link	Soft Link	AI			
17	~~Tunnel Booster Fan Sppedswith Alarm~~	~~VFC~~	~~24 VDC~~				
	Air Compressor outgoing Breaker-1						
1	Air Compressor Breaker On status	VFC	24 VDC			1	
2	Air Compressor Breaker Trip	VFC	24 VDC			1	
3	Air Compressor Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
	Air Compressor outgoing Breaker-2						
1	Air Compressor Breaker On status	VFC	24 VDC			1	
2	Air Compressor Breaker Trip	VFC	24 VDC			1	
3	Air Compressor Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
	FROM FIELD						
	Air Compressor, (AC-301)						
1	Running Status	VFC	24 VDC			1	
2	Trip Status	VFC	24 VDC			1	
4	Low Pressure Alarm	VFC	24 VDC			1	
	Tunnel Temperature Monitoring (NORTH)						
1	UP Line Space Temperature(JW-TT-001)	4-20 mA	4-20 mA	1			
2	DN Line Space Temperature(JW-TT-002)	4-20 mA	4-20 mA	1			
	LHDS DATA						
1	Temp Monitoring Data For LHDS	Soft Link	Soft Link	AI			
		Hard Signal		31	0	172	49
		Soft Signal		39	0	7	0

Sl No	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	SIGNAL TYPE AI	AO	DI	DO
	FROM DB-240						
	MDB-240 Incoming Breaker						
1	ATS/PLC Auto/Manual Status	Soft Link	Soft Link			DI	
2	Primary Breaker Trip status	Soft Link	Soft Link			DI	
3	Primary Breaker Open status	Soft Link	Soft Link			DI	
4	Primary Breaker Close status	Soft Link	Soft Link			DI	
5	Secondary Breaker Trip Status	Soft Link	Soft Link			DI	
6	Secondary Breaker Open Status	Soft Link	Soft Link			DI	
7	Secondary Breaker Close Status	Soft Link	Soft Link			DI	
8	Incoming Feeder Line Voltage	Soft Link	Soft Link	AI			
9	Incoming Feeder Line Current	Soft Link	Soft Link	AI			
10	Incoming Feeder Volt Ampere (VA)	Soft Link	Soft Link	AI			
11	Incoming Feeder Frequency (Hz)	Soft Link	Soft Link	AI			
12	Incoming Feeder Power Factor (PF)	Soft Link	Soft Link	AI			
13	Incoming Feeder Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
14	Incoming Feeder Volt Ampere Reactive (VAR)	Soft Link	Soft Link	AI			
15	Dual Supply Status	VFC	24 VDC			1	
16	Main supply off alarm	VFC	24 VDC			1	
17	~~Incoming Feeder Protection Relay Operation Status~~						
18	~~DB-240 Local Remote Status~~						
	TUNNEL VENTILATION FAN (TVF-203)						
1	Tunnel Ventilation Fan Local / Remote Switch Status	VFC	24 VDC			1	
2	Tunnel Ventilation Fan Forward ON / OFF Command	230 VAC	VFC				1
3	Tunnel Ventilation Fan Reverse ON / OFF Command	230 VAC	VFC				1
4	Tunnel Ventilation Fan Forward Run status	VFC	24 VDC			1	
5	Tunnel Ventilation Fan Reverse Run status	VFC	24 VDC			1	
6	Tunnel Ventilation Fan Emergency Stop Button Position	VFC	24 VDC			1	
7	Tunnel Ventilation Fan Motor Trip	VFC	24 VDC			1	
8	Tunnel Ventilation Fan FID Close status	VFC	24 VDC			1	
9	Tunnel Ventilation Fan FID Open status	VFC	24 VDC			1	
10	Tunnel Ventilation Fan Motor Current	4-20 mA	4-20 mA	1			
11	Tunnel Ventilation Fan Vibration Sensor	4-20 mA	4-20 mA	1			
12	Tunnel Ventilation Fan Forward Air Flow status	VFC	24 VDC			1	
13	Tunnel Ventilation Fan Reverse Air Flow status	VFC	24 VDC			1	
14	Tunnel Ventilation Fan Winding Thermal over load Alarm	VFC	24 VDC			1	
15	Tunnel Ventilation Fan Group Bypass Command	230 VAC	VFC				1
16	Tunnel Ventilation Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
17	No of start	Soft Link	Soft Link	AI			
18	Running Hours	Soft Link	Soft Link	AI			
19	~~Tunnel Vendilation Fan Sppedswith Alarm~~	~~VFC~~	~~24 VDC~~				
	TUNNEL VENTILATION FAN (TVF-204)						
1	Tunnel Ventilation Fan Local / Remote Switch Status	VFC	24 VDC			1	
2	Tunnel Ventilation Fan Forward ON / OFF Command	230 VAC	VFC				1
3	Tunnel Ventilation Fan Reverse ON / OFF Command	230 VAC	VFC				1
4	Tunnel Ventilation Fan Forward Run status	VFC	24 VDC			1	
5	Tunnel Ventilation Fan Reverse Run status	VFC	24 VDC			1	
6	Tunnel Ventilation Fan Emergency Stop Button Position	VFC	24 VDC			1	
7	Tunnel Ventilation Fan Motor Trip	VFC	24 VDC			1	
8	Tunnel Ventilation Fan FID Close status	VFC	24 VDC			1	
9	Tunnel Ventilation Fan FID Open status	VFC	24 VDC			1	
10	Tunnel Ventilation Fan Motor Current	4-20 mA	4-20 mA	1			
11	Tunnel Ventilation Fan Vibration Sensor	4-20 mA	4-20 mA	1			
12	Tunnel Ventilation Fan Forward Air Flow status	VFC	24 VDC			1	
13	Tunnel Ventilation Fan Reverse Air Flow status	VFC	24 VDC			1	
14	Tunnel Ventilation Fan Winding Thermal over load Alarm	VFC	24 VDC			1	
15	Tunnel Ventilation Fan Group Bypass Command	230 VAC	VFC				1
16	Tunnel Ventilation Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
17	No of start	Soft Link	Soft Link	AI			
18	Running Hours	Soft Link	Soft Link	AI			
19	~~Tunnel Vendilation Fan Sppedswith Alarm~~	~~VFC~~	~~24 VDC~~				
	RETURN DAMPER (TVD-203)						
1	Damper Local/Remote Switch Status	VFC	24 VDC			1	
2	Damper Open Position	VFC	24 VDC			1	

Sl No	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	SIGNAL TYPE AI	AO	DI	DO
3	Damper Close Position	VFC	24 VDC			1	
4	Damper Trip Status	VFC	24 VDC			1	
5	Damper Open/Close Command	230 VAC	VFC				1
	RETURN DAMPER (TVD-204)						
1	Damper Local/Remote Switch Status	VFC	24 VDC			1	
2	Damper Open Position	VFC	24 VDC			1	
3	Damper Close Position	VFC	24 VDC			1	
4	Damper Trip Status	VFC	24 VDC			1	
5	Damper Open/Close Command	230 VAC	VFC				1
	DRAFT RELIEF DAMPER (DRD-203)						
1	Damper Local/Remote Switch Status	VFC	24 VDC			1	
2	Damper Open Position	VFC	24 VDC			1	
3	Damper Close Position	VFC	24 VDC			1	
4	Damper Trip Status	VFC	24 VDC			1	
5	Damper Open/Close Command	230 VAC	VFC				1
	DRAFT RELIEF DAMPER (DRD-204)						
1	Damper Local/Remote Switch Status	VFC	24 VDC			1	
2	Damper Open Position	VFC	24 VDC			1	
3	Damper Close Position	VFC	24 VDC			1	
4	Damper Trip Status	VFC	24 VDC			1	
5	Damper Open/Close Command	230 VAC	VFC				1
	ENVIRONMENT DRAFT RELIEF DAMPER (ETVD-302)						
1	Damper Local/Remote Switch Status	VFC	24 VDC			1	
2	Damper Open Position	VFC	24 VDC			1	
3	Damper Close Position	VFC	24 VDC			1	
4	Damper Trip Status	VFC	24 VDC			1	
5	Damper Open/Close Command	230 VAC	VFC				1
	EXHAUST SHAFT DAMPER (SD-302)						
1	Damper Local/Remote Switch Status	VFC	24 VDC			1	
2	Damper Open Position	VFC	24 VDC			1	
3	Damper Close Position	VFC	24 VDC			1	
4	Damper Trip Status	VFC	24 VDC			1	
5	Damper Open/Close Command	230 VAC	VFC				1
	SPARE DAMPER (SPARE-TVD)						
1	Damper Local/Remote Switch Status	VFC	24 VDC			1	
2	Damper Open Position	VFC	24 VDC			1	
3	Damper Close Position	VFC	24 VDC			1	
4	Damper Trip Status	VFC	24 VDC			1	
5	Damper Open/Close Command	230 VAC	VFC				1
	FROM DB-230						
	TRACKWAY EXHAUST FAN (TEF-304)						
1	Trackway Exhaust Fan Local / Remote Switch Status	VFC	24 VDC			1	
2	Trackway Exhaust Fan ON / OFF Command	230 VAC	VFC				1
3	Trackway Exhaust Fan Run status	VFC	24 VDC			1	
4	Trackway Exhaust Fan Emergency Stop Button Position	VFC	24 VDC			1	
5	Trackway Exhaust Fan Motor Trip	VFC	24 VDC			1	
6	Trackway Exhaust Fan FID Close status	VFC	24 VDC			1	
7	Trackway Exhaust Fan FID Open status	VFC	24 VDC			1	
8	Trackway Exhaust Fan Air Flow status	VFC	24 VDC			1	
9	Trackway Exhaust Fan Motor Current	4-20 mA	4-20 mA	1			
10	Trackway Exhaust Fan Vibration Sensor	4-20 mA	4-20 mA	1			
11	Trackway Exhaust Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
12	Trackway Exhaust Fan Winding Thermal over load Alarm	4-20 mA	4-20 mA	1			
13	Trackway Exhaust Fan Group Bypass Command	230 VAC	VFC				1
14	~~Trackway Exhaust Fan SpeedSwitch Alarm~~	~~VFC~~	~~24 VDC~~				
	TRACKWAY EXHAUST FAN (TEF-305)						
1	Trackway Exhaust Fan Local / Remote Switch Status	VFC	24 VDC			1	
2	Trackway Exhaust Fan ON / OFF Command	230 VAC	VFC				1
3	Trackway Exhaust Fan Run status	VFC	24 VDC			1	
4	Trackway Exhaust Fan Emergency Stop Button Position	VFC	24 VDC			1	
5	Trackway Exhaust Fan Motor Trip	VFC	24 VDC			1	
6	Trackway Exhaust Fan FID Close status	VFC	24 VDC			1	
7	Trackway Exhaust Fan FID Open status	VFC	24 VDC			1	

Sl No	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	SIGNAL TYPE AI	AO	DI	DO
8	Trackway Exhaust Fan Air Flow status	VFC	24 VDC			1	
9	Trackway Exhaust Fan Motor Current	4-20 mA	4-20 mA	1			
10	Trackway Exhaust Fan Vibration Sensor	4-20 mA	4-20 mA	1			
11	Trackway Exhaust Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
12	Trackway Exhaust Fan Winding Thermal over load Alarm	4-20 mA	4-20 mA	1			
13	Trackway Exhaust Fan Group Bypass Command	230 VAC	VFC				1
14	~~Trackway Exhaust Fan SpeedSwitch Alarm~~	~~VFC~~	~~24 VDC~~				
	TRACKWAY EXHAUST FAN (TEF-306)						
1	Trackway Exhaust Fan Local / Remote Switch Status	VFC	24 VDC			1	
2	Trackway Exhaust Fan ON / OFF Command	230 VAC	VFC				1
3	Trackway Exhaust Fan Run status	VFC	24 VDC			1	
4	Trackway Exhaust Fan Emergency Stop Button Position	VFC	24 VDC			1	
5	Trackway Exhaust Fan Motor Trip	VFC	24 VDC			1	
6	Trackway Exhaust Fan FID Close status	VFC	24 VDC			1	
7	Trackway Exhaust Fan FID Open status	VFC	24 VDC			1	
8	Trackway Exhaust Fan Air Flow status	VFC	24 VDC			1	
9	Trackway Exhaust Fan Motor Current	4-20 mA	4-20 mA	1			
10	Trackway Exhaust Fan Vibration Sensor	4-20 mA	4-20 mA	1			
11	Trackway Exhaust Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
12	Trackway Exhaust Fan Winding Thermal over load Alarm	4-20 mA	4-20 mA	1			
13	Trackway Exhaust Fan Group Bypass Command	230 VAC	VFC				1
14	~~Trackway Exhaust Fan SpeedSwitch Alarm~~	~~VFC~~	~~24 VDC~~				
	SPARE TRACKWAY EXHAUST FAN (SPARE-TEF)						
1	Trackway Exhaust Fan Local / Remote Switch Status	VFC	24 VDC			1	
2	Trackway Exhaust Fan ON / OFF Command	230 VAC	VFC				1
3	Trackway Exhaust Fan Run status	VFC	24 VDC			1	
4	Trackway Exhaust Fan Emergency Stop Button Position	VFC	24 VDC			1	
5	Trackway Exhaust Fan Motor Trip	VFC	24 VDC			1	
6	Trackway Exhaust Fan FID Close status	VFC	24 VDC			1	
7	Trackway Exhaust Fan FID Open status	VFC	24 VDC			1	
8	Trackway Exhaust Fan Motor Current	4-20 mA	4-20 mA	1			
9	Trackway Exhaust Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
10	Trackway Exhaust Fan Group Bypass Command	230 VAC	VFC				1
11	~~Trackway Exhaust Fan SpeedSwitch Alarm~~	~~VFC~~	~~24 VDC~~				
	SMOKE EXHAUST FAN (SEF-303)						
1	Somke Exhaust Fan Local / Remote Switch Status	VFC	24 VDC			1	
2	Somke Exhaust Fan ON / OFF Command	230 VAC	VFC				1
3	Somke Exhaust Fan Run status	VFC	24 VDC			1	
4	Somke Exhaust Fan Emergency Stop Button Position	VFC	24 VDC			1	
5	Somke Exhaust Fan Motor Trip	VFC	24 VDC			1	
6	Somke Exhaust Fan FID Close status	VFC	24 VDC			1	
7	Somke Exhaust Fan FID Open status	VFC	24 VDC			1	
8	Somke Exhaust Fan Air Flow status	VFC	24 VDC			1	
9	Somke Exhaust Fan Motor Current	4-20 mA	4-20 mA	1			
10	Somke Exhaust FAN Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
11	Somke Exhaust Fan GroupByPass Command	230 VAC	VFC				1
	SMOKE EXHAUST FAN (SEF-304)						
1	Somke Exhaust Fan Local / Remote Switch Status	VFC	24 VDC			1	
2	Somke Exhaust Fan ON / OFF Command	230 VAC	VFC				1
3	Somke Exhaust Fan Run status	VFC	24 VDC			1	
4	Somke Exhaust Fan Emergency Stop Button Position	VFC	24 VDC			1	
5	Somke Exhaust Fan Motor Trip	VFC	24 VDC			1	
6	Somke Exhaust Fan FID Close status	VFC	24 VDC			1	
7	Somke Exhaust Fan FID Open status	VFC	24 VDC			1	
8	Somke Exhaust Fan Air Flow status	VFC	24 VDC			1	
9	Somke Exhaust Fan Motor Current	4-20 mA	4-20 mA	1			
10	Somke Exhaust FAN Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
11	Somke Exhaust Fan GroupByPass Command	230 VAC	VFC				1
	SPARE SMOKE EXHAUST FAN (SPARE-SEF)						
1	Somke Exhaust Fan Local / Remote Switch Status	VFC	24 VDC			1	
2	Somke Exhaust Fan ON / OFF Command	230 VAC	VFC				1
3	Somke Exhaust Fan Run status	VFC	24 VDC			1	
4	Somke Exhaust Fan Emergency Stop Button Position	VFC	24 VDC			1	

Sl No	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	SIGNAL TYPE AI	AO	DI	DO
5	Somke Exhaust Fan Motor Trip	VFC	24 VDC			1	
6	Somke Exhaust Fan FID Close status	VFC	24 VDC			1	
7	Somke Exhaust Fan FID Open status	VFC	24 VDC			1	
8	Somke Exhaust Fan Motor Current	4-20 mA	4-20 mA	1			
9	Somke Exhaust FAN Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
10	Somke Exhaust Fan GroupByPass Command	230 VAC	VFC				1
	STAIRCASE PRESSURIZATION FAN (SPF-302)						
1	STAIRCASE PRESSURIZATION FAN Local / Remote Switch Status	VFC	24 VDC			1	
2	STAIRCASE PRESSURIZATION FAN ON / OFF Command	230 VAC	VFC				1
3	STAIRCASE PRESSURIZATION FAN Run status	VFC	24 VDC			1	
4	STAIRCASE PRESSURIZATION FAN Emergency Stop Button Position	VFC	24 VDC			1	
5	STAIRCASE PRESSURIZATION FAN FID Close status	VFC	24 VDC			1	
6	STAIRCASE PRESSURIZATION FAN FID Open status	VFC	24 VDC			1	
7	STAIRCASE PRESSURIZATION FAN Motor Current	4-20 mA	4-20 mA	1			
8	STAIRCASE PRESSURIZATION FAN Motor Trip	VFC	24 VDC			1	
9	STAIRCASE PRESSURIZATION FAN Air Flow status	VFC	24 VDC			1	
10	STAIRCASE PRESSURIZATION FAN Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
11	STAIRCASE PRESSURIZATION FAN GroupByPass Command	230 VAC	VFC				1
	SPARE STAIRCASE PRESSURIZATION FAN (SPARE-SPF)						
1	STAIRCASE PRESSURIZATION FAN Local / Remote Switch Status	VFC	24 VDC			1	
2	STAIRCASE PRESSURIZATION FAN ON / OFF Command	230 VAC	VFC				1
3	STAIRCASE PRESSURIZATION FAN Run status	VFC	24 VDC			1	
4	STAIRCASE PRESSURIZATION FAN Emergency Stop Button Position	VFC	24 VDC			1	
5	STAIRCASE PRESSURIZATION FAN FID Close status	VFC	24 VDC			1	
6	STAIRCASE PRESSURIZATION FAN FID Open status	VFC	24 VDC			1	
7	STAIRCASE PRESSURIZATION FAN Motor Current	4-20 mA	4-20 mA	1			
8	STAIRCASE PRESSURIZATION FAN Motor Trip	VFC	24 VDC			1	
9	STAIRCASE PRESSURIZATION FAN Air Flow status	VFC	24 VDC			1	
10	STAIRCASE PRESSURIZATION FAN Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
11	STAIRCASE PRESSURIZATION FAN GroupByPass Command	230 VAC	VFC				1
	Fresh Air Fan, FAF-302						
1	Local/Remote Switch Status	Soft Link	Soft Link			DI	
2	On/Off Command	Soft Link	Soft Link				DO
3	Motor Running Feedback	Soft Link	Soft Link			DI	
4	Air Flow status	VFC	24 VDC			1	
5	Emergency Stop Button Position	Soft Link	Soft Link			DI	
6	Trip	Soft Link	Soft Link			DI	
7	FID Damper Open Position	VFC	24 VDC			1	
8	FID Damper Close Position	VFC	24 VDC			1	
9	Motor Current	Soft Link	Soft Link	AI			
10	Energy consumption Kwh	Soft Link	Soft Link	AI			
11	Fan Speed	Soft Link	Soft Link	AI			
	DB-TBF 690V Breaker-3						
1	ATS/PLC Auto/Manual Status	Soft Link	Soft Link			DI	
2	Primary Breaker Trip status	Soft Link	Soft Link			DI	
3	Primary Breaker Open status	Soft Link	Soft Link			DI	
4	Primary Breaker Close status	Soft Link	Soft Link			DI	
5	Secondary Breaker Trip Status	Soft Link	Soft Link			DI	
6	Secondary Breaker Open Status	Soft Link	Soft Link			DI	
7	Secondary Breaker Close Status	Soft Link	Soft Link			DI	
8	Incoming Feeder Line Voltage	Soft Link	Soft Link	AI			
9	Incoming Feeder Line Current	Soft Link	Soft Link	AI			
10	Incoming Feeder Volt Ampere (VA)	Soft Link	Soft Link	AI			
11	Incoming Feeder Frequency (Hz)	Soft Link	Soft Link	AI			
12	Incoming Feeder Power Factor (PF)	Soft Link	Soft Link	AI			
13	Incoming Feeder Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
14	Incoming Feeder Volt Ampere Reactive (VAR)	Soft Link	Soft Link	AI			
15	Dual Supply Status	VFC	24 VDC			1	
16	Main supply off alarm	VFC	24 VDC			1	
17	~~Incoming Feeder Protection Relay Operation Status~~						
18	~~DB-140 Local Remote Status~~						
	DB-TBF 690V Breaker-4						
1	ATS/PLC Auto/Manual Status	Soft Link	Soft Link			DI	

Sl No	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	SIGNAL TYPE			
				AI	AO	DI	DO
2	Primary Breaker Trip status	Soft Link	Soft Link			DI	
3	Primary Breaker Open status	Soft Link	Soft Link			DI	
4	Primary Breaker Close status	Soft Link	Soft Link			DI	
5	Secondary Breaker Trip Status	Soft Link	Soft Link			DI	
6	Secondary Breaker Open Status	Soft Link	Soft Link			DI	
7	Secondary Breaker Close Status	Soft Link	Soft Link			DI	
8	Incoming Feeder Line Voltage	Soft Link	Soft Link	AI			
9	Incoming Feeder Line Current	Soft Link	Soft Link	AI			
10	Incoming Feeder Volt Ampere (VA)	Soft Link	Soft Link	AI			
11	Incoming Feeder Frequency (Hz)	Soft Link	Soft Link	AI			
12	Incoming Feeder Power Factor (PF)	Soft Link	Soft Link	AI			
13	Incoming Feeder Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
14	Incoming Feeder Volt Ampere Reactive (VAR)	Soft Link	Soft Link	AI			
15	Dual Supply Status	VFC	24 VDC			1	
16	Main supply off alarm	VFC	24 VDC			1	
17	~~Incoming Feeder Protection Relay Operation Status~~						
18	~~DB-140 Local Remote Status~~						
	Tunnel Booster Fan (TBF-305)						
1	Tunnel Booster Fan Local / Remote Switch Status	VFC	24 VDC			1	
2	Tunnel Booster Fan Forward ON / OFF Command	230 VAC	VFC				1
3	Tunnel Booster Fan Reverse ON / OFF Command	230 VAC	VFC				1
4	Tunnel Booster Fan Forward Run status	VFC	24 VDC			1	
5	Tunnel Booster Fan Reverse Run status	VFC	24 VDC			1	
6	Tunnel Booster Fan Emergency Stop Button Position	VFC	24 VDC			1	
7	Tunnel Booster Fan Motor Trip	VFC	24 VDC			1	
8	Tunnel Booster Fan Motor Current	4-20 mA	4-20 mA	1			
9	Tunnel Booster Fan Vibration Sensor	4-20 mA	4-20 mA	1			
10	Tunnel Booster Fan Forward Air Flow status	VFC	24 VDC			1	
11	Tunnel Booster Fan Reverse Air Flow status	VFC	24 VDC			1	
12	Tunnel Booster Fan Winding Thermal over load Alarm	VFC	24 VDC			1	
13	Tunnel Booster Fan Group Bypass Command	230 VAC	VFC				1
14	Tunnel Booster Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
15	No of start	Soft Link	Soft Link	AI			
16	Running Hours	Soft Link	Soft Link	AI			
17	~~Tunnel Booster Fan Sppedswith Alarm~~	~~VFC~~	~~24 VDC~~				
	Tunnel Booster Fan (TBF-306)						
1	Tunnel Booster Fan Local / Remote Switch Status	VFC	24 VDC			1	
2	Tunnel Booster Fan Forward ON / OFF Command	230 VAC	VFC				1
3	Tunnel Booster Fan Reverse ON / OFF Command	230 VAC	VFC				1
4	Tunnel Booster Fan Forward Run status	VFC	24 VDC			1	
5	Tunnel Booster Fan Reverse Run status	VFC	24 VDC			1	
6	Tunnel Booster Fan Emergency Stop Button Position	VFC	24 VDC			1	
7	Tunnel Booster Fan Motor Trip	VFC	24 VDC			1	
8	Tunnel Booster Fan Motor Current	4-20 mA	4-20 mA	1			
9	Tunnel Booster Fan Vibration Sensor	4-20 mA	4-20 mA	1			
10	Tunnel Booster Fan Forward Air Flow status	VFC	24 VDC			1	
11	Tunnel Booster Fan Reverse Air Flow status	VFC	24 VDC			1	
12	Tunnel Booster Fan Winding Thermal over load Alarm	VFC	24 VDC			1	
13	Tunnel Booster Fan Group Bypass Command	230 VAC	VFC				1
14	Tunnel Booster Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
15	No of start	Soft Link	Soft Link	AI			
16	Running Hours	Soft Link	Soft Link	AI			
17	~~Tunnel Booster Fan Sppedswith Alarm~~	~~VFC~~	~~24 VDC~~				
	Tunnel Booster Fan (TBF-307)						
1	Tunnel Booster Fan Local / Remote Switch Status	VFC	24 VDC			1	
2	Tunnel Booster Fan Forward ON / OFF Command	230 VAC	VFC				1
3	Tunnel Booster Fan Reverse ON / OFF Command	230 VAC	VFC				1
4	Tunnel Booster Fan Forward Run status	VFC	24 VDC			1	
5	Tunnel Booster Fan Reverse Run status	VFC	24 VDC			1	
6	Tunnel Booster Fan Emergency Stop Button Position	VFC	24 VDC			1	
7	Tunnel Booster Fan Motor Trip	VFC	24 VDC			1	
8	Tunnel Booster Fan Motor Current	4-20 mA	4-20 mA	1			
9	Tunnel Booster Fan Vibration Sensor	4-20 mA	4-20 mA	1			

Sl No	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	SIGNAL TYPE			
				AI	AO	DI	DO
10	Tunnel Booster Fan Forward Air Flow status	VFC	24 VDC			1	
11	Tunnel Booster Fan Reverse Air Flow status	VFC	24 VDC			1	
12	Tunnel Booster Fan Winding Thermal over load Alarm	VFC	24 VDC			1	
13	Tunnel Booster Fan Group Bypass Command	230 VAC	VFC				1
14	Tunnel Booster Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
15	No of start	Soft Link	Soft Link	AI			
16	Running Hours	Soft Link	Soft Link	AI			
17	~~Tunnel Booster Fan Sppedswith Alarm~~	~~VFC~~	~~24 VDC~~				
	Tunnel Booster Fan (TBF-308)						
1	Tunnel Booster Fan Local / Remote Switch Status	VFC	24 VDC			1	
2	Tunnel Booster Fan Forward ON / OFF Command	230 VAC	VFC				1
3	Tunnel Booster Fan Reverse ON / OFF Command	230 VAC	VFC				1
4	Tunnel Booster Fan Forward Run status	VFC	24 VDC			1	
5	Tunnel Booster Fan Reverse Run status	VFC	24 VDC			1	
6	Tunnel Booster Fan Emergency Stop Button Position	VFC	24 VDC			1	
7	Tunnel Booster Fan Motor Trip	VFC	24 VDC			1	
8	Tunnel Booster Fan Motor Current	4-20 mA	4-20 mA	1			
9	Tunnel Booster Fan Vibration Sensor	4-20 mA	4-20 mA	1			
10	Tunnel Booster Fan Forward Air Flow status	VFC	24 VDC			1	
11	Tunnel Booster Fan Reverse Air Flow status	VFC	24 VDC			1	
12	Tunnel Booster Fan Winding Thermal over load Alarm	VFC	24 VDC			1	
13	Tunnel Booster Fan Group Bypass Command	230 VAC	VFC				1
14	Tunnel Booster Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
15	No of start	Soft Link	Soft Link	AI			
16	Running Hours	Soft Link	Soft Link	AI			
17	~~Tunnel Booster Fan Sppedswith Alarm~~	~~VFC~~	~~24 VDC~~				
	FROM FIELD						
	Tunnel Temperature Monitoring (SOUTH)						
1	UP Line Space Temperature(JW-TT-003)	4-20 mA	4-20 mA	1			
2	DN Line Space Temperature(JW-TT-004)	4-20 mA	4-20 mA	1			
	LHDS DATA						
1	Temp Monitoring Data For LHDS	Soft Link	Soft Link	AI			

	AI	AO	DI	DO
Hard Signal	29	0	148	43
Soft Signal	52	0	25	1

S. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	AI	AO	DI	DO
	FROM DB 130						
	MDB-130 Incoming Breaker						
1	ATS/PLC Auto/Manual Status	Soft Link	Soft Link			DI	
2	Primary Breaker Trip status	Soft Link	Soft Link			DI	
3	Primary Breaker Open status	Soft Link	Soft Link			DI	
4	Primary Breaker Close status	Soft Link	Soft Link			DI	
5	Secondary Breaker Trip Status	Soft Link	Soft Link			DI	
6	Secondary Breaker Open Status	Soft Link	Soft Link			DI	
7	Secondary Breaker Close Status	Soft Link	Soft Link			DI	
8	Incoming Feeder Line Voltage	Soft Link	Soft Link	AI			
9	Incoming Feeder Line Current	Soft Link	Soft Link	AI			
10	Incoming Feeder Volt Ampere (VA)	Soft Link	Soft Link	AI			
11	Incoming Feeder Frequency (Hz)	Soft Link	Soft Link	AI			
12	Incoming Feeder Power Factor (PF)	Soft Link	Soft Link	AI			
13	Incoming Feeder Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
14	Incoming Feeder Volt Ampere Reactive (VAR)	Soft Link	Soft Link	AI			
15	Dual Supply Status	VFC	24 VDC			1	
16	Main supply off alarm	VFC	24 VDC			1	
17	~~Incoming Feeder Protection Relay Operation Status~~						
18	~~DB-140 Local Remote Status~~						
	Capacitor Panel, DB-CAP-130 Incoming C.B. (ACB)						
1	Outgoing Breaker Trip Alarm	VFC	24 VDC			1	
2	Outgoing Breaker Close Status	VFC	24 VDC			1	
3	Outgoing Breaker Open Status	VFC	24 VDC			1	
4	Outgoing Feeder Line Voltage	4-20mA	4-20mA	1			
5	Outgoing Feeder Line Current	4-20mA	4-20mA	1			
6	Capacitor Bank Failure/APFC relay Alarm	VFC	24 VDC			1	
7	~~Capacitor Bank Off Status~~	VFC	24 VDC				
8	Capacitor Bank OverTemp Alarm	VFC	24 VDC			1	
9	APFC Data	Soft Link	Soft Link	AI			
10	~~Outgoing Feeder Protection Relay Operation Status~~	24 VDC					
11	~~Outgoing Breaker Local/Remote Status~~	VFC	24 VDC				
12	~~Outgoing Breaker Open Command~~	230 V	VFC				
13	~~Outgoing Breaker Close Command~~	230 V	VFC				
	Capacitor Panel, JW-DB-CAP-130 Outgoing CB						
1	Outgoing Breaker Trip Alarm	VFC	24 VDC			1	
2	Outgoing Breaker Close Status	VFC	24 VDC			1	
3	Outgoing Breaker Open Status	VFC	24 VDC			1	
4	Outgoing Feeder Line Voltage	4-20mA	4-20mA	1			
5	Outgoing Feeder Line Current	4-20mA	4-20mA	1			
6	~~Capacitor Bank Failure/APFC relay Alarm~~	~~VFC~~	~~24 VDC~~				
7	~~Capacitor Bank Off Status~~	~~VFC~~	~~24 VDC~~				
8	~~Capacitor Bank OverTemp Alarm~~	~~VFC~~	~~24 VDC~~				
9	~~APFC Data~~	~~Soft Link~~	~~Soft Link~~				
10	~~Outgoing Feeder Protection Relay Operation Status~~	24 VDC					
11	~~Outgoing Breaker Local/Remote Status~~	VFC	24 VDC				
12	~~Outgoing Breaker Open Command~~	230 V	VFC				
13	~~Outgoing Breaker Close Command~~	230 V	VFC				
	Air Handling Unit, AHU-301						
1	Motor # 01 Local/Remote Switch Status	VFC	24 VDC			1	
2	Motor # 01 On/Off Command	230 VAC	VFC				1
3	Motor # 01 Running Feedback	VFC	24 VDC			1	
4	Motor # 01 Air Flow status	VFC	24 VDC			1	
5	Motor # 01 Emergency Stop Button Position	VFC	24 VDC			1	
6	Motor # 01 Trip	VFC	24 VDC			1	
7	Motor # 01 Current	4-20mA	4-20mA	1			
8	MOD Damper Open Position Motor 1	VFC	24 VDC			1	

S. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	AI	AO	DI	DO
9	MOD Damper Close Position Motor 1	VFC	24 VDC			1	
10	Temperature Control Valve-1	4-20mA	4-20mA		1		
11	Filter Clog Status #M1	VFC	24 VDC			1	
12	Water Flow In line For M1	4-20mA	4-20mA	1			
13	Temperature Control Valve-1 Open Feedback	4-20mA	4-20mA	1			
14	AHU-M1 Kwhr	Soft Link	Soft Link	AI			
15	Motor # 02 Local/Remote Switch Status	VFC	24 VDC			1	
16	Motor # 02 On/Off Command	230 VAC	VFC				1
17	Motor # 02 Running Feedback	VFC	24 VDC			1	
18	Motor # 02 Air Flow status	VFC	24 VDC			1	
19	Motor # 02 Emergency Stop Button Position	VFC	24 VDC			1	
20	Motor # 02 Trip	VFC	24 VDC			1	
21	Motor # 02 Current	4-20mA	4-20mA	1			
22	MOD Damper Open Position Motor 2	VFC	24 VDC			1	
23	MOD Damper Close Position Motor 2	VFC	24 VDC			1	
24	Temperature Control Valve-2	4-20mA	4-20mA		1		
25	Filter Clog Status #M2	VFC	24 VDC			1	
26	Water Flow In line For M2	4-20mA	4-20mA	1			
27	Temperature Control Valve-2 Open Feedback	4-20mA	4-20mA	1			
28	AHU-M2 Kwhr	Soft Link	Soft Link	AI			
	Air Handling Unit, AHU-302						
1	Motor # 01 Local/Remote Switch Status	VFC	24 VDC			1	
2	Motor # 01 On/Off Command	230 VAC	VFC				1
3	Motor # 01 Running Feedback	VFC	24 VDC			1	
4	Motor # 01 Air Flow status	VFC	24 VDC			1	
5	Motor # 01 Emergency Stop Button Position	VFC	24 VDC			1	
6	Motor # 01 Trip	VFC	24 VDC			1	
7	Motor # 01 Current	4-20mA	4-20mA	1			
8	MOD Damper Open Position Motor 1	VFC	24 VDC			1	
9	MOD Damper Close Position Motor 1	VFC	24 VDC			1	
10	Temperature Control Valve-1	4-20mA	4-20mA		1		
11	Filter Clog Status #M1	VFC	24 VDC			1	
12	Water Flow In line For M1	4-20mA	4-20mA	1			
13	Temperature Control Valve-1 Open Feedback	4-20mA	4-20mA	1			
14	AHU-M1 Kwhr	Soft Link	Soft Link	AI			
15	Motor # 02 Local/Remote Switch Status	VFC	24 VDC			1	
16	Motor # 02 On/Off Command	230 VAC	VFC				1
17	Motor # 02 Running Feedback	VFC	24 VDC			1	
18	Motor # 02 Air Flow status	VFC	24 VDC			1	
25	Filter Clog Status #M2	VFC	24 VDC			1	
26	Water Flow In line For M2	4-20mA	4-20mA	1			
27	Temperature Control Valve-2 Open Feedback	4-20mA	4-20mA	1			
28	AHU-M2 Kwhr	Soft Link	Soft Link	AI			
	SPARE Air Handling Unit, SPARE-AHU						
1	Motor # 01 Local/Remote Switch Status	VFC	24 VDC			1	
2	Motor # 01 On/Off Command	230 VAC	VFC				1
3	Motor # 01 Running Feedback	VFC	24 VDC			1	
4	Motor # 01 Emergency Stop Button Position	VFC	24 VDC			1	
5	Motor # 01 Trip	VFC	24 VDC			1	
6	Motor # 01 Current	4-20mA	4-20mA	1			
7	MOD Damper Open Position Motor 1	VFC	24 VDC			1	
8	MOD Damper Close Position Motor 1	VFC	24 VDC			1	
9	AHU-M1 Kwhr	Soft Link	Soft Link	AI			
	SPARE Air Handling Unit, SPARE-AHU						
1	Motor # 01 Local/Remote Switch Status	VFC	24 VDC			1	

S. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	AI	AO	DI	DO
2	Motor # 01 On/Off Command	230 VAC	VFC				1
3	Motor # 01 Running Feedback	VFC	24 VDC			1	
4	Motor # 01 Emergency Stop Button Position	VFC	24 VDC			1	
5	Motor # 01 Trip	VFC	24 VDC			1	
6	Motor # 01 Current	4-20mA	4-20mA	1			
7	MOD Damper Open Position Motor 1	VFC	24 VDC			1	
8	MOD Damper Close Position Motor 1	VFC	24 VDC			1	
9	AHU-M1 Kwhr	Soft Link	Soft Link	AI			
	Ventilation Supply Fan, VSF-301						
1	Local/Remote Switch Status	VFC	24 VDC			1	
2	On/Off Command	230 VAC	VFC				1
3	Motor Running Feedback	VFC	24 VDC			1	
4	Air Flow status	VFC	24 VDC			1	
5	Emergency Stop Button Position	VFC	24 VDC			1	
6	Trip	VFC	24 VDC			1	
7	FID Damper Open Position	VFC	24 VDC			1	
8	FID Damper Close Position	VFC	24 VDC			1	
9	Motor Current	4-20mA	4-20mA	1			
10	Energy consumption Kwh	Soft Link	Soft Link	AI			
	Ventilation Supply Fan, VSF-302						
1	Local/Remote Switch Status	VFC	24 VDC			1	
2	On/Off Command	230 VAC	VFC				1
3	Motor Running Feedback	VFC	24 VDC			1	
4	Air Flow status	VFC	24 VDC			1	
5	Emergency Stop Button Position	VFC	24 VDC			1	
6	Trip	VFC	24 VDC			1	
7	FID Damper Open Position	VFC	24 VDC			1	
8	FID Damper Close Position	VFC	24 VDC			1	
9	Motor Current	4-20mA	4-20mA	1			
10	Energy consumption Kwh	Soft Link	Soft Link	AI			
	Ventilation Exhaust Fan, VEF-301						
1	Local/Remote Switch Status	VFC	24 VDC			1	
2	On/Off Command	230 VAC	VFC				1
3	Motor Running Feedback	VFC	24 VDC			1	
4	Air Flow status	VFC	24 VDC			1	
5	Emergency Stop Button Position	VFC	24 VDC			1	
6	Trip	VFC	24 VDC			1	
7	FID Damper Open Position	VFC	24 VDC			1	
8	FID Damper Close Position	VFC	24 VDC			1	
9	Motor Current	4-20mA	4-20mA	1			
10	Energy consumption Kwh	Soft Link	Soft Link	AI			
	Ventilation Exhaust Fan, VEF-302						
1	Local/Remote Switch Status	VFC	24 VDC			1	
2	On/Off Command	230 VAC	VFC				1
3	Motor Running Feedback	VFC	24 VDC			1	
4	Air Flow status	VFC	24 VDC			1	
5	Emergency Stop Button Position	VFC	24 VDC			1	
6	Trip	VFC	24 VDC			1	
7	FID Damper Open Position	VFC	24 VDC			1	
8	FID Damper Close Position	VFC	24 VDC			1	
9	Motor Current	4-20mA	4-20mA	1			
10	Energy consumption Kwh	Soft Link	Soft Link	AI			
	Ventilation Exhaust Fan, VEF-201						

S. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	AI	AO	DI	DO
1	Local/Remote Switch Status	VFC	24 VDC			1	
2	On/Off Command	230 VAC	VFC				1
3	Motor Running Feedback	VFC	24 VDC			1	
4	Air Flow status	VFC	24 VDC			1	
5	Emergency Stop Button Position	VFC	24 VDC			1	
6	Trip	VFC	24 VDC			1	
7	FID Damper Open Position	VFC	24 VDC			1	
8	FID Damper Close Position	VFC	24 VDC			1	
9	Motor Current	4-20mA	4-20mA	1			
10	Energy consumption Kwh	Soft Link	Soft Link	AI			
	Ventilation Exhaust Fan, VEF-202						
1	Local/Remote Switch Status	VFC	24 VDC			1	
2	On/Off Command	230 VAC	VFC				1
3	Motor Running Feedback	VFC	24 VDC			1	
4	Air Flow status	VFC	24 VDC			1	
5	Emergency Stop Button Position	VFC	24 VDC			1	
6	Trip	VFC	24 VDC			1	
7	FID Damper Open Position	VFC	24 VDC			1	
8	FID Damper Close Position	VFC	24 VDC			1	
9	Motor Current	4-20mA	4-20mA	1			
10	Energy consumption Kwh	Soft Link	Soft Link	AI			
	Ventilation Exhaust Fan, VEF-801						
1	Local/Remote Switch Status	VFC	24 VDC			1	
2	On/Off Command	230 VAC	VFC				1
3	Motor Running Feedback	VFC	24 VDC			1	
4	Air Flow status	VFC	24 VDC			1	
5	Emergency Stop Button Position	VFC	24 VDC			1	
6	Trip	VFC	24 VDC			1	
7	FID Damper Open Position	VFC	24 VDC			1	
8	FID Damper Close Position	VFC	24 VDC			1	
9	Motor Current	4-20mA	4-20mA	1			
10	Energy consumption Kwh	Soft Link	Soft Link	AI			
	Ventilation Exhaust Fan, VEF-802						
1	Local/Remote Switch Status	VFC	24 VDC			1	
2	On/Off Command	230 VAC	VFC				1
3	Motor Running Feedback	VFC	24 VDC			1	
4	Air Flow status	VFC	24 VDC			1	
5	Emergency Stop Button Position	VFC	24 VDC			1	
6	Trip	VFC	24 VDC			1	
7	FID Damper Open Position	VFC	24 VDC			1	
8	FID Damper Close Position	VFC	24 VDC			1	
9	Motor Current	4-20mA	4-20mA	1			
10	Energy consumption Kwh	Soft Link	Soft Link	AI			
	Spare Ventilation Exhaust Fan, SPARE-VEF						
1	Local/Remote Switch Status	VFC	24 VDC			1	
2	On/Off Command	230 VAC	VFC				1
3	Motor Running Feedback	VFC	24 VDC			1	
4	Emergency Stop Button Position	VFC	24 VDC			1	
5	Trip	VFC	24 VDC			1	
6	FID Damper Open Position	VFC	24 VDC			1	
7	FID Damper Close Position	VFC	24 VDC			1	
8	Motor Current	4-20mA	4-20mA	1			
9	Energy consumption Kwh	Soft Link	Soft Link	AI			
	Spare Ventilation Exhaust Fan, SPARE-VEF (ASS Room)						
1	Local/Remote Switch Status	VFC	24 VDC			1	
2	On/Off Command	230 VAC	VFC				1
3	Motor Running Feedback	VFC	24 VDC			1	
4	Emergency Stop Button Position	VFC	24 VDC			1	

S. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	AI	AO	DI	DO
5	Trip	VFC	24 VDC			1	
6	FID Damper Open Position	VFC	24 VDC			1	
7	FID Damper Close Position	VFC	24 VDC			1	
8	Motor Current	4-20mA	4-20mA	1			
9	Energy consumption Kwh	Soft Link	Soft Link	AI			
	Fresh Air Fan, FAF-301 (VFD)						
1	Local/Remote Switch Status	Soft Link	Soft Link			DI	
2	On/Off Command	Soft Link	Soft Link				DO
3	Motor Running Feedback	Soft Link	Soft Link			DI	
4	Air Flow status	VFC	24 VDC			1	
5	Emergency Stop Button Position	Soft Link	Soft Link			DI	
6	Trip	Soft Link	Soft Link			DI	
7	FID Damper Open Position	VFC	24 VDC			1	
8	FID Damper Close Position	VFC	24 VDC			1	
9	Motor Current	Soft Link	Soft Link	AI			
10	Energy consumption Kwh	Soft Link	Soft Link	AI			
11	Fan Speed	Soft Link	Soft Link	AI			
	Motorised Dampers Distribution Board, DB-131 Outgoing C.B.						
1	Outgoing Breaker Trip Alarm	VFC	24 VDC			1	
2	Outgoing Breaker Close Status	VFC	24 VDC			1	
3	Outgoing Breaker Open Status	VFC	24 VDC			1	
	FROM DB- 131						
	Motorised Dampers Distribution Board, DB-131 Incoming C.B.						
1	~~Incoming Breaker Local/Remote Status~~	VFC	24 VDC				
2	Incoming Breaker Trip Alarm	VFC	24 VDC			1	
3	Incoming Breaker Close Status	VFC	24 VDC			1	
4	Incoming Breaker Open Status	VFC	24 VDC			1	
5	Mains Incoming Voltage	4-20mA	4-20mA	1			
6	Incoming Feeder Line Current	4-20mA	4-20mA	1			
7	Incoming Feeder Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
8	~~Feeder Protection Relay Operation Status~~						
	Motorized Dampers (MOD) - MFD-201						
1	MFD Damper Open Position	VFC	24 VDC			1	
2	MFD Damper Close Position	VFC	24 VDC			1	
3	MFD Trip Status	VFC	24 VDC			1	
4	MFD Damper Open/ Close Command	230 VAC	VFC				1
5	MFD Local/Remote Switch Status	VFC	24 VDC			1	
	Motorized Fire Dampers (MFD) - MFD-202						
1	MFD Damper Open Position	VFC	24 VDC			1	
2	MFD Damper Close Position	VFC	24 VDC			1	
3	MFD Trip Status	VFC	24 VDC			1	
4	MFD Damper Open/ Close Command	230 VAC	VFC				1
5	MFD Local/Remote Switch Status	VFC	24 VDC			1	
	Motorized Fire Dampers (MFD) - MFD-203						
1	MFD Damper Open Position	VFC	24 VDC			1	
2	MFD Damper Close Position	VFC	24 VDC			1	
3	MFD Trip Status	VFC	24 VDC			1	
4	MFD Damper Open/ Close Command	230 VAC	VFC				1
5	MFD Local/Remote Switch Status	VFC	24 VDC			1	
	Motorized Fire Dampers (MFD) - MFD-204						
1	MFD Damper Open Position	VFC	24 VDC			1	
2	MFD Damper Close Position	VFC	24 VDC			1	
3	MFD Trip Status	VFC	24 VDC			1	
4	MFD Damper Open/ Close Command	230 VAC	VFC				1

S. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	AI	AO	DI	DO
5	MFD Local/Remote Switch Status	VFC	24 VDC			1	
	Motorized Fire Dampers (MFD) - MFD-205						
1	MFD Damper Open Position	VFC	24 VDC			1	
2	MFD Damper Close Position	VFC	24 VDC			1	
3	MFD Trip Status	VFC	24 VDC			1	
4	MFD Damper Open/ Close Command	230 VAC	VFC				1
5	MFD Local/Remote Switch Status	VFC	24 VDC			1	
	Motorized Dampers (MOD) - MOD-301						
1	MFD Damper Open Position	VFC	24 VDC			1	
2	MFD Damper Close Position	VFC	24 VDC			1	
3	MFD Trip Status	VFC	24 VDC			1	
4	MFD Damper Open/ Close Command	230 VAC	VFC				1
5	MFD Local/Remote Switch Status	VFC	24 VDC			1	
	Motorized Fire Dampers (MFD) - MFD-303						
1	MFD Damper Open Position	VFC	24 VDC			1	
2	MFD Damper Close Position	VFC	24 VDC			1	
3	MFD Trip Status	VFC	24 VDC			1	
4	MFD Damper Open/ Close Command	230 VAC	VFC				1
5	MFD Local/Remote Switch Status	VFC	24 VDC			1	
	Motorized Fire Dampers (MFD) - MFD-307						
1	MFD Damper Open Position	VFC	24 VDC			1	
2	MFD Damper Close Position	VFC	24 VDC			1	
3	MFD Trip Status	VFC	24 VDC			1	
4	MFD Damper Open/ Close Command	230 VAC	VFC				1
5	MFD Local/Remote Switch Status	VFC	24 VDC			1	
	Motorized Fire Dampers (MFD) - MFD-308						
1	MFD Damper Open Position	VFC	24 VDC			1	
2	MFD Damper Close Position	VFC	24 VDC			1	
3	MFD Trip Status	VFC	24 VDC			1	
4	MFD Damper Open/ Close Command	230 VAC	VFC				1
5	MFD Local/Remote Switch Status	VFC	24 VDC			1	
	Motorized Fire Dampers (MFD) - MFD-309						
1	MFD Damper Open Position	VFC	24 VDC			1	
2	MFD Damper Close Position	VFC	24 VDC			1	
3	MFD Trip Status	VFC	24 VDC			1	
4	MFD Damper Open/ Close Command	230 VAC	VFC				1
5	MFD Local/Remote Switch Status	VFC	24 VDC			1	
	Motorized Fire Dampers (MFD) - MFD-310						
1	MFD Damper Open Position	VFC	24 VDC			1	
2	MFD Damper Close Position	VFC	24 VDC			1	
3	MFD Trip Status	VFC	24 VDC			1	
4	MFD Damper Open/ Close Command	230 VAC	VFC				1
5	MFD Local/Remote Switch Status	VFC	24 VDC			1	
	Motorized Dampers (MOD) - MOD-311						
1	MFD Damper Open Position	VFC	24 VDC			1	
2	MFD Damper Close Position	VFC	24 VDC			1	
3	MFD Trip Status	VFC	24 VDC			1	
4	MFD Damper Open/ Close Command	230 VAC	VFC				1
5	MFD Local/Remote Switch Status	VFC	24 VDC			1	
	Motorized Fire Dampers (MFD) - MFD-334						
1	MFD Damper Open Position	VFC	24 VDC			1	
2	MFD Damper Close Position	VFC	24 VDC			1	
3	MFD Trip Status	VFC	24 VDC			1	
4	MFD Damper Open/ Close Command	230 VAC	VFC				1
5	MFD Local/Remote Switch Status	VFC	24 VDC			1	
	Split Units/FCU Distribution Board, DB-132 Outgoing C.B.						
1	Outgoing Breaker Trip Alarm	VFC	24 VDC			1	
2	Outgoing Breaker Close Status	VFC	24 VDC			1	

S. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	AI	AO	DI	DO
3	Outgoing Breaker Open Status	VFC	24 VDC			1	
	FROM DB 132						
	Split Units/FCU Distribution Board, DB-132 Incoming C.B.						
1	~~Incoming Breaker Local/Remote Status~~	VFC	24 VDC				
2	Incoming Breaker Trip Alarm	VFC	24 VDC			1	
3	Incoming Breaker Close Status	VFC	24 VDC			1	
4	Incoming Breaker Open Status	VFC	24 VDC			1	
5	Incoming Feeder Line Current	4-20mA	4-20mA	1			
6	Mains Incoming Voltage	4-20mA	4-20mA	1			
7	Energy consumption Kwh	Soft Link	Soft Link	AI			
8	FCU ON OFF Status (25 no of Soft Signal /As requird)	Soft Link	Soft Link	AI			
	FROM FIELD						
	Public Area Lighting LDB-8						
1	Local/Remote Status	VFC	24 VDC			1	
2	On/Off Command - Circuit 1	230 VAC	VFC				1
3	On/Off Status - Circuit 1	VFC	24 VDC			1	
4	On/Off Command - Circuit 2	230 VAC	VFC				1
5	On/Off Status - Circuit 2	VFC	24 VDC			1	
6	On/Off Command - Circuit 3	230 VAC	VFC				1
7	On/Off Status - Circuit 3	VFC	24 VDC			1	
8	Dual Supply Healthy Status	VFC	24 VDC			1	
9	Energy consumption Kwh	Soft Link	Soft Link	AI			
10	~~Local/Remote Status - Circuit 2~~	VFC	24 VDC				
11	~~Local/Remote Status - Circuit 3~~	VFC	24 VDC				
	Public Area Lighting LDB-9						
1	Local/Remote Status	VFC	24 VDC			1	
2	On/Off Command - Circuit 1	230 VAC	VFC				1
3	On/Off Status - Circuit 1	VFC	24 VDC			1	
4	On/Off Command - Circuit 2	230 VAC	VFC				1
5	On/Off Status - Circuit 2	VFC	24 VDC			1	
6	On/Off Command - Circuit 3	230 VAC	VFC				1
7	On/Off Status - Circuit 3	VFC	24 VDC			1	
8	Dual Supply Healthy Status	VFC	24 VDC			1	
9	Energy consumption Kwh	Soft Link	Soft Link	AI			
10	~~Local/Remote Status - Circuit 2~~	VFC	24 VDC				
11	~~Local/Remote Status - Circuit 3~~	VFC	24 VDC				
	Public Area Lighting LDB-10						
1	Local/Remote Status	VFC	24 VDC			1	
2	On/Off Command - Circuit 1	230 VAC	VFC				1
3	On/Off Status - Circuit 1	VFC	24 VDC			1	
4	On/Off Command - Circuit 2	230 VAC	VFC				1
5	On/Off Status - Circuit 2	VFC	24 VDC			1	
6	On/Off Command - Circuit 3	230 VAC	VFC				1
7	On/Off Status - Circuit 3	VFC	24 VDC			1	
8	Dual Supply Healthy Status	VFC	24 VDC			1	
9	Energy consumption Kwh	Soft Link	Soft Link	AI			
10	~~Local/Remote Status - Circuit 2~~	VFC	24 VDC				
11	~~Local/Remote Status - Circuit 3~~	VFC	24 VDC				
	Public Area Lighting UDB-4 (BOH CONC)						
1	Local/Remote Status	VFC	24 VDC			1	
2	On/Off Command - Circuit 1	230 VAC	VFC				1
3	On/Off Status - Circuit 1	VFC	24 VDC			1	
4	On/Off Command - Circuit 2	230 VAC	VFC				1
5	On/Off Status - Circuit 2	VFC	24 VDC			1	

S. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	AI	AO	DI	DO
6	On/Off Command - Circuit 3	230 VAC	VFC				1
7	On/Off Status - Circuit 3	VFC	24 VDC			1	
8	Dual Supply Healthy Status	VFC	24 VDC			1	
9	Energy consumption Kwh	Soft Link	Soft Link	AI			
10	~~Local/Remote Status - Circuit 2~~	VFC	24 VDC				
11	~~Local/Remote Status - Circuit 3~~	VFC	24 VDC				
	Air Temperature & RH Monitoting						
1	Supply Air Plenum Temperature	4-20mA	4-20mA	1			
2	Supply Air Relative Humidity (RH)	4-20mA	4-20mA	1			
3	Return Air Temperature	4-20mA	4-20mA	1			
4	Return Air Relative Humidity (RH)	4-20mA	4-20mA	1			
	Platform/Concourse Temperature & RH Monitoting						
1	NORTH End Concourse RH	4-20mA	4-20mA	1			
2	NORTH End Concourse Temperature	4-20mA	4-20mA	1			
~~3~~	~~NORTH End Platform RH~~	~~4-20mA~~	~~4-20mA~~				
~~4~~	~~NORTH End Platform Temperature~~	~~4-20mA~~	~~4-20mA~~				
5	CO2 Sensor	4-20mA	4-20mA	1			

	AI	AO	DI	DO
Hard Signal	38	3	205	41
Soft Signal	34	0	11	1

S. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	TYPE			
				AI	AO	DI	DO
	FROM DB230						
	MDB-230 Incoming Breaker						
1	ATS/PLC Auto/Manual Status	Soft Link	Soft Link			DI	
2	Primary Breaker Trip status	Soft Link	Soft Link			DI	
3	Primary Breaker Open status	Soft Link	Soft Link			DI	
4	Primary Breaker Close status	Soft Link	Soft Link			DI	
5	Secondary Breaker Trip Status	Soft Link	Soft Link			DI	
6	Secondary Breaker Open Status	Soft Link	Soft Link			DI	
7	Secondary Breaker Close Status	Soft Link	Soft Link			DI	
8	Incoming Feeder Line Voltage	Soft Link	Soft Link	AI			
9	Incoming Feeder Line Current	Soft Link	Soft Link	AI			
10	Incoming Feeder Volt Ampere (VA)	Soft Link	Soft Link	AI			
11	Incoming Feeder Frequency (Hz)	Soft Link	Soft Link	AI			
12	Incoming Feeder Power Factor (PF)	Soft Link	Soft Link	AI			
13	Incoming Feeder Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
14	Incoming Feeder Volt Ampere Reactive (VAR)	Soft Link	Soft Link	AI			
15	Dual Supply Status	VFC	24 VDC			1	
16	Main supply off alarm	VFC	24 VDC			1	
17	~~Incoming Feeder Protection Relay Operation Status~~						
18	~~DB-230 Local Remote Status~~						
	Capacitor Panel, DB-CAP-230 Incoming C.B. (ACB)						
1	Outgoing Breaker Trip Alarm	VFC	24 VDC			1	
2	Outgoing Breaker Close Status	VFC	24 VDC			1	
3	Outgoing Breaker Open Status	VFC	24 VDC			1	
4	Outgoing Feeder Line Voltage	4-20mA	4-20mA	1			
5	Outgoing Feeder Line Current	4-20mA	4-20mA	1			
6	Capacitor Bank Failure/APFC relay Alarm	VFC	24 VDC			1	
7	~~Capacitor Bank Off Status~~	VFC	24 VDC				
8	Capacitor Bank OverTemp Alarm	VFC	24 VDC			1	
9	APFC Data	Soft Link	Soft Link	AI			
10	~~Outgoing Feeder Protection Relay Operation Status~~	24 VDC					
11	~~Outgoing Breaker Local/Remote Status~~	VFC	24 VDC				
12	~~Outgoing Breaker Open Command~~	230 V	VFC				
13	~~Outgoing Breaker Close Command~~	230 V	VFC				
	Capacitor Panel, DB-CAP-230 Outgoing CB						
1	Outgoing Breaker Trip Alarm	VFC	24 VDC			1	
2	Outgoing Breaker Close Status	VFC	24 VDC			1	
3	Outgoing Breaker Open Status	VFC	24 VDC			1	
4	Outgoing Feeder Line Voltage	4-20mA	4-20mA	1			
5	Outgoing Feeder Line Current	4-20mA	4-20mA	1			
6	~~Capacitor Bank Failure/APFC relay Alarm~~	~~VFC~~	~~24 VDC~~				
7	~~Capacitor Bank Off Status~~	~~VFC~~	~~24 VDC~~				
8	~~Capacitor Bank OverTemp Alarm~~	~~VFC~~	~~24 VDC~~				
9	~~APFC Data~~	~~Soft Link~~	~~Soft Link~~				
10	~~Outgoing Feeder Protection Relay Operation Status~~	24 VDC					
11	~~Outgoing Breaker Local/Remote Status~~	VFC	24 VDC				
12	~~Outgoing Breaker Open Command~~	230 V	VFC				
13	~~Outgoing Breaker Close Command~~	230 V	VFC				
	Air Handling Unit,AHU-303						
1	Motor # 01 Local/Remote Switch Status	VFC	24 VDC			1	
2	Motor # 01 On/Off Command	230 VAC	VFC				1
3	Motor # 01 Running Feedback	VFC	24 VDC			1	
4	Motor # 01 Air Flow status	VFC	24 VDC			1	
5	Motor # 01 Emergency Stop Button Position	VFC	24 VDC			1	
6	Motor # 01 Trip	VFC	24 VDC			1	
7	Motor # 01 Current	4-20mA	4-20mA	1			
8	MOD Damper Open Position Motor 1	VFC	24 VDC			1	
9	MOD Damper Close Position Motor 1	VFC	24 VDC			1	
10	Temperature Control Valve-1	4-20mA	4-20mA		1		
11	Filter Clog Status #M1	VFC	24 VDC			1	
12	Water Flow In line For M1	4-20mA	4-20mA	1			
13	Temperature Control Valve-1 Open Feedback	4-20mA	4-20mA	1			
14	AHU-M1 Kwhr	Soft Link	Soft Link	AI			
15	Motor # 02 Local/Remote Switch Status	VFC	24 VDC			1	
16	Motor # 02 On/Off Command	230 VAC	VFC				1
17	Motor # 02 Running Feedback	VFC	24 VDC			1	

S. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	TYPE			
				AI	AO	DI	DO
18	Motor # 02 Air Flow status	VFC	24 VDC			1	
19	Motor # 02 Emergency Stop Button Position	VFC	24 VDC			1	
20	Motor # 02 Trip	VFC	24 VDC			1	
21	Motor # 02 Current	4-20mA	4-20mA	1			
22	MOD Damper Open Position Motor 2	VFC	24 VDC			1	
23	MOD Damper Close Position Motor 2	VFC	24 VDC			1	
24	Temperature Control Valve-2	4-20mA	4-20mA		1		
25	Filter Clog Status #M2	VFC	24 VDC			1	
26	Water Flow In line For M2	4-20mA	4-20mA	1			
27	Temperature Control Valve-2 Open Feedback	4-20mA	4-20mA	1			
28	AHU-M2 Kwhr	Soft Link	Soft Link	AI			
	Air Handling Unit, AHU-304						
1	Motor # 01 Local/Remote Switch Status	VFC	24 VDC			1	
2	Motor # 01 On/Off Command	230 VAC	VFC				1
3	Motor # 01 Running Feedback	VFC	24 VDC			1	
4	Motor # 01 Air Flow status	VFC	24 VDC			1	
5	Motor # 01 Emergency Stop Button Position	VFC	24 VDC			1	
6	Motor # 01 Trip	VFC	24 VDC			1	
7	Motor # 01 Current	4-20mA	4-20mA	1			
8	MOD Damper Open Position Motor 1	VFC	24 VDC			1	
9	MOD Damper Close Position Motor 1	VFC	24 VDC			1	
10	Temperature Control Valve-1	4-20mA	4-20mA		1		
11	Filter Clog Status #M1	VFC	24 VDC			1	
12	Water Flow In line For M1	4-20mA	4-20mA	1			
13	Temperature Control Valve-1 Open Feedback	4-20mA	4-20mA	1			
14	AHU-M1 Kwhr	Soft Link	Soft Link	AI			
15	Motor # 02 Local/Remote Switch Status	VFC	24 VDC			1	
16	Motor # 02 On/Off Command	230 VAC	VFC				1
17	Motor # 02 Running Feedback	VFC	24 VDC			1	
18	Motor # 02 Air Flow status	VFC	24 VDC			1	
25	Filter Clog Status #M2	VFC	24 VDC			1	
26	Water Flow In line For M2	4-20mA	4-20mA	1			
27	Temperature Control Valve-2 Open Feedback	4-20mA	4-20mA	1			
28	AHU-M2 Kwhr	Soft Link	Soft Link	AI			
	Spare Air Handling Unit, SPARE-AHU						
1	Motor # 01 Local/Remote Switch Status	VFC	24 VDC			1	
2	Motor # 01 On/Off Command	230 VAC	VFC				1
3	Motor # 01 Running Feedback	VFC	24 VDC			1	
4	Motor # 01 Emergency Stop Button Position	VFC	24 VDC			1	
5	Motor # 01 Trip	VFC	24 VDC			1	
6	Motor # 01 Current	4-20mA	4-20mA	1			
7	MOD Damper Open Position Motor 1	VFC	24 VDC			1	
8	MOD Damper Close Position Motor 1	VFC	24 VDC			1	
9	AHU-M1 Kwhr	Soft Link	Soft Link	AI			
	SPARE Air Handling Unit, SPARE-AHU						
1	Motor # 01 Local/Remote Switch Status	VFC	24 VDC			1	
2	Motor # 01 On/Off Command	230 VAC	VFC				1
3	Motor # 01 Running Feedback	VFC	24 VDC			1	
4	Motor # 01 Emergency Stop Button Position	VFC	24 VDC			1	
5	Motor # 01 Trip	VFC	24 VDC			1	
6	Motor # 01 Current	4-20mA	4-20mA	1			
7	MOD Damper Open Position Motor 1	VFC	24 VDC			1	
8	MOD Damper Close Position Motor 1	VFC	24 VDC			1	
9	AHU-M1 Kwhr	Soft Link	Soft Link	AI			
	Ventilation Supply Fan, VSF-303						
1	Local/Remote Switch Status	VFC	24 VDC			1	
2	On/Off Command	230 VAC	VFC				1
3	Motor Running Feedback	VFC	24 VDC			1	
4	Air Flow status	VFC	24 VDC			1	
5	Emergency Stop Button Position	VFC	24 VDC			1	
6	Trip	VFC	24 VDC			1	
7	FID Damper Open Position	VFC	24 VDC			1	

S. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	TYPE			
				AI	AO	DI	DO
8	FID Damper Close Position	VFC	24 VDC			1	
9	Motor Current	4-20mA	4-20mA	1			
10	Energy consumption Kwh	Soft Link	Soft Link	AI			
	Ventilation Supply Fan, VSF-304						
1	Local/Remote Switch Status	VFC	24 VDC			1	
2	On/Off Command	230 VAC	VFC				1
3	Motor Running Feedback	VFC	24 VDC			1	
4	Air Flow status	VFC	24 VDC			1	
5	Emergency Stop Button Position	VFC	24 VDC			1	
6	Trip	VFC	24 VDC			1	
7	FID Damper Open Position	VFC	24 VDC			1	
8	FID Damper Close Position	VFC	24 VDC			1	
9	Motor Current	4-20mA	4-20mA	1			
10	Energy consumption Kwh	Soft Link	Soft Link	AI			
	Ventilation Exhaust Fan, VEF-303						
1	Local/Remote Switch Status	VFC	24 VDC			1	
2	On/Off Command	230 VAC	VFC				1
3	Motor Running Feedback	VFC	24 VDC			1	
4	Air Flow status	VFC	24 VDC			1	
5	Emergency Stop Button Position	VFC	24 VDC			1	
6	Trip	VFC	24 VDC			1	
7	FID Damper Open Position	VFC	24 VDC			1	
8	FID Damper Close Position	VFC	24 VDC			1	
9	Motor Current	4-20mA	4-20mA	1			
10	Energy consumption Kwh	Soft Link	Soft Link	AI			
	Ventilation Exhaust Fan, VEF-304						
1	Local/Remote Switch Status	VFC	24 VDC			1	
2	On/Off Command	230 VAC	VFC				1
3	Motor Running Feedback	VFC	24 VDC			1	
4	Air Flow status	VFC	24 VDC			1	
5	Emergency Stop Button Position	VFC	24 VDC			1	
6	Trip	VFC	24 VDC			1	
7	FID Damper Open Position	VFC	24 VDC			1	
8	FID Damper Close Position	VFC	24 VDC			1	
9	Motor Current	4-20mA	4-20mA	1			
10	Energy consumption Kwh	Soft Link	Soft Link	AI			
	Ventilation Exhaust Fan, VEF-203						
1	Local/Remote Switch Status	VFC	24 VDC			1	
2	On/Off Command	230 VAC	VFC				1
3	Motor Running Feedback	VFC	24 VDC			1	
4	Air Flow status	VFC	24 VDC			1	
5	Emergency Stop Button Position	VFC	24 VDC			1	
6	Trip	VFC	24 VDC			1	
7	FID Damper Open Position	VFC	24 VDC			1	
8	FID Damper Close Position	VFC	24 VDC			1	
9	Motor Current	4-20mA	4-20mA	1			
10	Energy consumption Kwh	Soft Link	Soft Link	AI			
	Ventilation Exhaust Fan, VEF-204						
1	Local/Remote Switch Status	VFC	24 VDC			1	
2	On/Off Command	230 VAC	VFC				1
3	Motor Running Feedback	VFC	24 VDC			1	
4	Air Flow status	VFC	24 VDC			1	
5	Emergency Stop Button Position	VFC	24 VDC			1	
6	Trip	VFC	24 VDC			1	
7	FID Damper Open Position	VFC	24 VDC			1	
8	FID Damper Close Position	VFC	24 VDC			1	
9	Motor Current	4-20mA	4-20mA	1			
10	Energy consumption Kwh	Soft Link	Soft Link	AI			
	Ventilation Exhaust Fan, VEF-205						
1	Local/Remote Switch Status	VFC	24 VDC			1	
2	On/Off Command	230 VAC	VFC				1

S. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	TYPE			
				AI	AO	DI	DO
3	Motor Running Feedback	VFC	24 VDC			1	
4	Air Flow status	VFC	24 VDC			1	
5	Emergency Stop Button Position	VFC	24 VDC			1	
6	Trip	VFC	24 VDC			1	
7	FID Damper Open Position	VFC	24 VDC			1	
8	FID Damper Close Position	VFC	24 VDC			1	
9	Motor Current	4-20mA	4-20mA	1			
10	Energy consumption Kwh	Soft Link	Soft Link	AI			
	Ventilation Exhaust Fan, VEF-206						
1	Local/Remote Switch Status	VFC	24 VDC			1	
2	On/Off Command	230 VAC	VFC				1
3	Motor Running Feedback	VFC	24 VDC			1	
4	Air Flow status	VFC	24 VDC			1	
5	Emergency Stop Button Position	VFC	24 VDC			1	
6	Trip	VFC	24 VDC			1	
7	FID Damper Open Position	VFC	24 VDC			1	
8	FID Damper Close Position	VFC	24 VDC			1	
9	Motor Current	4-20mA	4-20mA	1			
10	Energy consumption Kwh	Soft Link	Soft Link	AI			
	Spare Ventilation Exhaust Fan, SPARE-VEF						
1	Local/Remote Switch Status	VFC	24 VDC			1	
2	On/Off Command	230 VAC	VFC				1
3	Motor Running Feedback	VFC	24 VDC			1	
4	Emergency Stop Button Position	VFC	24 VDC			1	
5	Trip	VFC	24 VDC			1	
6	FID Damper Open Position	VFC	24 VDC			1	
7	FID Damper Close Position	VFC	24 VDC			1	
8	Motor Current	4-20mA	4-20mA	1			
9	Energy consumption Kwh	Soft Link	Soft Link	AI			
	Spare Ventilation Exhaust Fan, SPARE-VEF (ASS Room)						
1	Local/Remote Switch Status	VFC	24 VDC			1	
2	On/Off Command	230 VAC	VFC				1
3	Motor Running Feedback	VFC	24 VDC			1	
4	Emergency Stop Button Position	VFC	24 VDC			1	
5	Trip	VFC	24 VDC			1	
6	FID Damper Open Position	VFC	24 VDC			1	
7	FID Damper Close Position	VFC	24 VDC			1	
8	Motor Current	4-20mA	4-20mA	1			
9	Energy consumption Kwh	Soft Link	Soft Link	AI			
	Motorised Dampers Distribution Board, DB-231 Outgoing C.B.						
1	Outgoing Breaker Trip Alarm	VFC	24 VDC			1	
2	Outgoing Breaker Close Status	VFC	24 VDC			1	
3	Outgoing Breaker Open Status	VFC	24 VDC			1	
	FROM -DB 231						
	Motorised Dampers Distribution Board, DB-231						
1	Incoming Breaker Local/Remote Status	VFC	24 VDC			1	
2	Incoming Breaker Trip Alarm	VFC	24 VDC			1	
3	Incoming Breaker Close Status	VFC	24 VDC			1	
4	Incoming Breaker Open Status	VFC	24 VDC			1	
5	Mains Incoming Voltage	4-20mA	4-20mA	1			
6	Incoming Feeder Line Current	4-20mA	4-20mA	1			
7	Incoming Feeder Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
8	~~Feeder Protection Relay Operation Status~~						
	Motorized Fire Dampers (MFD) -MFD-207						
1	MFD Damper Open Position	VFC	24 VDC			1	
2	MFD Damper Close Position	VFC	24 VDC			1	
3	MFD Trip Status	VFC	24 VDC			1	
4	MFD Damper Open/ Close Command	230 VAC	VFC				1
5	MFD Local/Remote Switch Status	VFC	24 VDC			1	
	Motorized Fire Dampers (MFD) -MFD-208						
1	MFD Damper Open Position	VFC	24 VDC			1	
2	MFD Damper Close Position	VFC	24 VDC			1	
3	MFD Trip Status	VFC	24 VDC			1	

S. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	TYPE			
				AI	AO	DI	DO
4	MFD Damper Open/ Close Command	230 VAC	VFC				1
5	MFD Local/Remote Switch Status	VFC	24 VDC			1	
	Motorized Fire Dampers (MFD) -MFD-209						
1	MFD Damper Open Position	VFC	24 VDC			1	
2	MFD Damper Close Position	VFC	24 VDC			1	
3	MFD Trip Status	VFC	24 VDC			1	
4	MFD Damper Open/ Close Command	230 VAC	VFC				1
5	MFD Local/Remote Switch Status	VFC	24 VDC			1	
	Motorized Dampers (MOD) -MOD-311						
1	MFD Damper Open Position	VFC	24 VDC			1	
2	MFD Damper Close Position	VFC	24 VDC			1	
3	MFD Trip Status	VFC	24 VDC			1	
4	MFD Damper Open/ Close Command	230 VAC	VFC				1
5	MFD Local/Remote Switch Status	VFC	24 VDC			1	
	Motorized Fire Dampers (MFD) -MFD-313						
1	MFD Damper Open Position	VFC	24 VDC			1	
2	MFD Damper Close Position	VFC	24 VDC			1	
3	MFD Trip Status	VFC	24 VDC			1	
4	MFD Damper Open/ Close Command	230 VAC	VFC				1
5	MFD Local/Remote Switch Status	VFC	24 VDC			1	
	Motorized Fire Dampers (MFD) -MFD-317						
1	MFD Damper Open Position	VFC	24 VDC			1	
2	MFD Damper Close Position	VFC	24 VDC			1	
3	MFD Trip Status	VFC	24 VDC			1	
4	MFD Damper Open/ Close Command	230 VAC	VFC				1
5	MFD Local/Remote Switch Status	VFC	24 VDC			1	
	Motorized Fire Dampers (MFD) -MFD-318						
1	MFD Damper Open Position	VFC	24 VDC			1	
2	MFD Damper Close Position	VFC	24 VDC			1	
3	MFD Trip Status	VFC	24 VDC			1	
4	MFD Damper Open/ Close Command	230 VAC	VFC				1
5	MFD Local/Remote Switch Status	VFC	24 VDC			1	
	Motorized Fire Dampers (MFD) -MFD-319						
1	MFD Damper Open Position	VFC	24 VDC			1	
2	MFD Damper Close Position	VFC	24 VDC			1	
3	MFD Trip Status	VFC	24 VDC			1	
4	MFD Damper Open/ Close Command	230 VAC	VFC				1
5	MFD Local/Remote Switch Status	VFC	24 VDC			1	
	Motorized Fire Dampers (MFD) -MFD-320						
1	MFD Damper Open Position	VFC	24 VDC			1	
2	MFD Damper Close Position	VFC	24 VDC			1	
3	MFD Trip Status	VFC	24 VDC			1	
4	MFD Damper Open/ Close Command	230 VAC	VFC				1
5	MFD Local/Remote Switch Status	VFC	24 VDC			1	
	Motorized Fire Dampers (MFD) -MFD-321						
1	MFD Damper Open Position	VFC	24 VDC			1	
2	MFD Damper Close Position	VFC	24 VDC			1	
3	MFD Trip Status	VFC	24 VDC			1	
4	MFD Damper Open/ Close Command	230 VAC	VFC				1
5	MFD Local/Remote Switch Status	VFC	24 VDC			1	
	Motorized Fire Dampers (MFD) -MFD-322						
1	MFD Damper Open Position	VFC	24 VDC			1	
2	MFD Damper Close Position	VFC	24 VDC			1	
3	MFD Trip Status	VFC	24 VDC			1	
4	MFD Damper Open/ Close Command	230 VAC	VFC				1
5	MFD Local/Remote Switch Status	VFC	24 VDC			1	
	Motorized Fire Dampers (MFD) -MFD-323						
1	MFD Damper Open Position	VFC	24 VDC			1	
2	MFD Damper Close Position	VFC	24 VDC			1	
3	MFD Trip Status	VFC	24 VDC			1	
4	MFD Damper Open/ Close Command	230 VAC	VFC				1
5	MFD Local/Remote Switch Status	VFC	24 VDC			1	
	Motorized Fire Dampers (MFD) -MFD-324						
1	MFD Damper Open Position	VFC	24 VDC			1	
2	MFD Damper Close Position	VFC	24 VDC			1	
3	MFD Trip Status	VFC	24 VDC			1	
4	MFD Damper Open/ Close Command	230 VAC	VFC				1
5	MFD Local/Remote Switch Status	VFC	24 VDC			1	

S. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	TYPE			
				AI	AO	DI	DO
	Motorized Fire Dampers (MFD) -MFD-325						
1	MFD Damper Open Position	VFC	24 VDC			1	
2	MFD Damper Close Position	VFC	24 VDC			1	
3	MFD Trip Status	VFC	24 VDC			1	
4	MFD Damper Open/ Close Command	230 VAC	VFC				1
5	MFD Local/Remote Switch Status	VFC	24 VDC			1	
	Motorized Fire Dampers (MFD) -MFD-333						
1	MFD Damper Open Position	VFC	24 VDC			1	
2	MFD Damper Close Position	VFC	24 VDC			1	
3	MFD Trip Status	VFC	24 VDC			1	
4	MFD Damper Open/ Close Command	230 VAC	VFC				1
5	MFD Local/Remote Switch Status	VFC	24 VDC			1	
	Motorized Fire Dampers (MFD) -MFD-335						
1	MFD Damper Open Position	VFC	24 VDC			1	
2	MFD Damper Close Position	VFC	24 VDC			1	
3	MFD Trip Status	VFC	24 VDC			1	
4	MFD Damper Open/ Close Command	230 VAC	VFC				1
5	MFD Local/Remote Switch Status	VFC	24 VDC			1	
	Motorized Fire Dampers (MFD) -MFD-336						
1	MFD Damper Open Position	VFC	24 VDC			1	
2	MFD Damper Close Position	VFC	24 VDC			1	
3	MFD Trip Status	VFC	24 VDC			1	
4	MFD Damper Open/ Close Command	230 VAC	VFC				1
5	MFD Local/Remote Switch Status	VFC	24 VDC			1	
	Motorized Fire Dampers (MFD) -MFD-337						
1	MFD Damper Open Position	VFC	24 VDC			1	
2	MFD Damper Close Position	VFC	24 VDC			1	
3	MFD Trip Status	VFC	24 VDC			1	
4	MFD Damper Open/ Close Command	230 VAC	VFC				1
5	MFD Local/Remote Switch Status	VFC	24 VDC			1	
	Motorized Fire Dampers (MFD) -MFD-338						
1	MFD Damper Open Position	VFC	24 VDC			1	
2	MFD Damper Close Position	VFC	24 VDC			1	
3	MFD Trip Status	VFC	24 VDC			1	
4	MFD Damper Open/ Close Command	230 VAC	VFC				1
5	MFD Local/Remote Switch Status	VFC	24 VDC			1	
	Motorized Fire Dampers (MFD) -MFD-339						
1	MFD Damper Open Position	VFC	24 VDC			1	
2	MFD Damper Close Position	VFC	24 VDC			1	
3	MFD Trip Status	VFC	24 VDC			1	
4	MFD Damper Open/ Close Command	230 VAC	VFC				1
5	MFD Local/Remote Switch Status	VFC	24 VDC			1	
	Motorized Fire Dampers (MFD) -MFD-340						
1	MFD Damper Open Position	VFC	24 VDC			1	
2	MFD Damper Close Position	VFC	24 VDC			1	
3	MFD Trip Status	VFC	24 VDC			1	
4	MFD Damper Open/ Close Command	230 VAC	VFC				1
5	MFD Local/Remote Switch Status	VFC	24 VDC			1	
	Split Units/FCU Distribution Board, DB-232 Outgoing C.B.						
1	Outgoing Breaker Trip Alarm	VFC	24 VDC			1	
2	Outgoing Breaker Close Status	VFC	24 VDC			1	
3	Outgoing Breaker Open Status	VFC	24 VDC			1	
	FROM DB 232						
	Split Units/FCU Distribution Board, DB-232						
1	~~Incoming Breaker Local/Remote Status~~	VFC	24 VDC				
2	Incoming Breaker Trip Alarm	VFC	24 VDC			1	
3	Incoming Breaker Close Status	VFC	24 VDC			1	
4	Incoming Breaker Open Status	VFC	24 VDC			1	
5	Incoming Feeder Line Current	4-20mA	4-20mA	1			
6	Mains Incoming Voltage	4-20mA	4-20mA	1			
7	Energy consumption Kwh	Soft Link	Soft Link	AI			
8	FCU ON OFF Status (25 no of Soft Signal /As requird)	Soft Link	Soft Link	AI			
	FROM FIELD						
	Public Area Lighting LDB-5						

S. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	TYPE			
				AI	AO	DI	DO
1	Local/Remote Status	VFC	24 VDC			1	
2	On/Off Command - Circuit 1	230 VAC	VFC				1
3	On/Off Status - Circuit 1	VFC	24 VDC			1	
4	On/Off Command - Circuit 2	230 VAC	VFC				1
5	On/Off Status - Circuit 2	VFC	24 VDC			1	
6	On/Off Command - Circuit 3	230 VAC	VFC				1
7	On/Off Status - Circuit 3	VFC	24 VDC			1	
8	Dual Supply Healthy Status	VFC	24 VDC			1	
9	Energy consumption Kwh	Soft Link	Soft Link	AI			
10	~~Local/Remote Status - Circuit 2~~	VFC	24 VDC				
11	~~Local/Remote Status - Circuit 3~~	VFC	24 VDC				
	Public Area Lighting LDB-6						
1	Local/Remote Status	VFC	24 VDC			1	
2	On/Off Command - Circuit 1	230 VAC	VFC				1
3	On/Off Status - Circuit 1	VFC	24 VDC			1	
4	On/Off Command - Circuit 2	230 VAC	VFC				1
5	On/Off Status - Circuit 2	VFC	24 VDC			1	
6	On/Off Command - Circuit 3	230 VAC	VFC				1
7	On/Off Status - Circuit 3	VFC	24 VDC			1	
8	Dual Supply Healthy Status	VFC	24 VDC			1	
9	Energy consumption Kwh	Soft Link	Soft Link	AI			
10	~~Local/Remote Status - Circuit 2~~	VFC	24 VDC				
11	~~Local/Remote Status - Circuit 3~~	VFC	24 VDC				
	Public Area Lighting LDB-7						
1	Local/Remote Status	VFC	24 VDC			1	
2	On/Off Command - Circuit 1	230 VAC	VFC				1
3	On/Off Status - Circuit 1	VFC	24 VDC			1	
4	On/Off Command - Circuit 2	230 VAC	VFC				1
5	On/Off Status - Circuit 2	VFC	24 VDC			1	
6	On/Off Command - Circuit 3	230 VAC	VFC				1
7	On/Off Status - Circuit 3	VFC	24 VDC			1	
8	Dual Supply Healthy Status	VFC	24 VDC			1	
9	Energy consumption Kwh	Soft Link	Soft Link	AI			
10	~~Local/Remote Status - Circuit 2~~	VFC	24 VDC				
11	~~Local/Remote Status - Circuit 3~~	VFC	24 VDC				
	Public Area Lighting LDB-11						
1	Local/Remote Status	VFC	24 VDC			1	
2	On/Off Command - Circuit 1	230 VAC	VFC				1
3	On/Off Status - Circuit 1	VFC	24 VDC			1	
4	On/Off Command - Circuit 2	230 VAC	VFC				1
5	On/Off Status - Circuit 2	VFC	24 VDC			1	
6	On/Off Command - Circuit 3	230 VAC	VFC				1
7	On/Off Status - Circuit 3	VFC	24 VDC			1	
8	Dual Supply Healthy Status	VFC	24 VDC			1	
9	Energy consumption Kwh	Soft Link	Soft Link	AI			
10	~~Local/Remote Status - Circuit 2~~	VFC	24 VDC				
11	~~Local/Remote Status - Circuit 3~~	VFC	24 VDC				
	Public Area Lighting UDB Concourse UDB-9 (BOH CONC)						
1	Local/Remote Status	VFC	24 VDC			1	
2	On/Off Command - Circuit 1	230 VAC	VFC				1
3	On/Off Status - Circuit 1	VFC	24 VDC			1	
4	On/Off Command - Circuit 2	230 VAC	VFC				1
5	On/Off Status - Circuit 2	VFC	24 VDC			1	
6	On/Off Command - Circuit 3	230 VAC	VFC				1
7	On/Off Status - Circuit 3	VFC	24 VDC			1	
8	Dual Supply Healthy Status	VFC	24 VDC			1	
9	Energy consumption Kwh	Soft Link	Soft Link	AI			
10	~~Local/Remote Status - Circuit 2~~	VFC	24 VDC				
11	~~Local/Remote Status - Circuit 3~~	VFC	24 VDC				
	Public Area Lighting UDB Concourse UDB-10 (PUBLIC AREA CONC)						
1	Local/Remote Status	VFC	24 VDC			1	
2	On/Off Command - Circuit 1	230 VAC	VFC				1

S. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	TYPE			
				AI	AO	DI	DO
3	On/Off Status - Circuit 1	VFC	24 VDC			1	
4	On/Off Command - Circuit 2	230 VAC	VFC				1
5	On/Off Status - Circuit 2	VFC	24 VDC			1	
6	On/Off Command - Circuit 3	230 VAC	VFC				1
7	On/Off Status - Circuit 3	VFC	24 VDC			1	
8	Dual Supply Healthy Status	VFC	24 VDC			1	
9	Energy consumption Kwh	Soft Link	Soft Link	AI			
10	~~Local/Remote Status - Circuit 2~~	VFC	24 VDC				
11	~~Local/Remote Status - Circuit 3~~	VFC	24 VDC				
	Air Temperature & RH Monitoting						
1	Supply Air Plenum Temperature	4-20mA	4-20mA	1			
2	Supply Air Relative Humidity (RH)	4-20mA	4-20mA	1			
3	Return Air Temperature	4-20mA	4-20mA	1			
4	Return Air Relative Humidity (RH)	4-20mA	4-20mA	1			
	Platform/Concourse Temperature & RH Monitoting						
1	SOUTH End Concourse RH	4-20mA	4-20mA	1			
2	SOUTH End Concourse Temperature	4-20mA	4-20mA	1			
~~3~~	~~SOUTH End Platform RH~~						
~~4~~	~~SOUTH End Platform Temperature~~						
5	CO2 Sensor	4-20mA	4-20mA	1			
			Hard Signal	38	3	245	55
			Soft Signal	33	0	7	0

S. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	SIGNAL TYPE			
				AI	AO	DI	DO
	FROM DB 170/270						
	MDB-170/270 Incoming Circuit Breaker Tranformer #3						
1	Incoming Breaker Local/Remote Status	VFC	24 VDC			1	
2	Incoming Breaker Trip Alarm	Soft Link	Soft Link			DI	
3	Incoming Breaker Close Status	Soft Link	Soft Link			DI	
4	Incoming Breaker Open Status	Soft Link	Soft Link			DI	
5	Incoming Feeder Line Voltage	Soft Link	Soft Link	AI			
6	Incoming Feeder Line Current	Soft Link	Soft Link	AI			
7	Incoming Feeder Volt Ampere (VA)	Soft Link	Soft Link	AI			
8	Incoming Feeder Frequency (Hz)	Soft Link	Soft Link	AI			
9	Incoming Feeder Power Factor (PF)	Soft Link	Soft Link	AI			
10	Incoming Feeder Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
11	Incoming Feeder Volt Ampere Reactive (VAR)	Soft Link	Soft Link	AI			
12	Control Supply Status	VFC	24 VDC			1	
13	Incoming Breaker Open Command	230VAC	VFC				1
14	Incoming Breaker Close Command	230VAC	VFC				1
15	~~Incoming Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
16	~~Tie Breaker Close Status - ASS1 TO ASS3~~	~~VFC~~	~~24 VDC~~				
17	~~Tie Breaker Open Status - ASS1 TO ASS3~~	~~VFC~~	~~24 VDC~~				
	MDB-170/270 Incoming Circuit Breaker Tranformer #4						
1	Incoming Breaker Local/Remote Status	VFC	24 VDC			1	
2	Incoming Breaker Trip Alarm	Soft Link	Soft Link			DI	
3	Incoming Breaker Close Status	Soft Link	Soft Link			DI	
4	Incoming Breaker Open Status	Soft Link	Soft Link			DI	
5	Incoming Feeder Line Voltage	Soft Link	Soft Link	AI			
6	Incoming Feeder Line Current	Soft Link	Soft Link	AI			
7	Incoming Feeder Volt Ampere (VA)	Soft Link	Soft Link	AI			
8	Incoming Feeder Frequency (Hz)	Soft Link	Soft Link	AI			
9	Incoming Feeder Power Factor (PF)	Soft Link	Soft Link	AI			
10	Incoming Feeder Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
11	Incoming Feeder Volt Ampere Reactive (VAR)	Soft Link	Soft Link	AI			
12	Control Supply Status	VFC	24 VDC			1	
13	Incoming Breaker Open Command	230VAC	VFC				1
14	Incoming Breaker Close Command	230VAC	VFC				1
15	~~Incoming Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
16	~~Tie Breaker Close Status - ASS1 TO ASS3~~	~~VFC~~	~~24 VDC~~				
17	~~Tie Breaker Open Status - ASS1 TO ASS3~~	~~VFC~~	~~24 VDC~~				
	MDB-170/270 Incoming Circuit Breaker DB 200						
1	Incoming Breaker Local/Remote Status	VFC	24 VDC			1	
2	Incoming Breaker Trip Alarm	Soft Link	Soft Link			DI	
3	Incoming Breaker Close Status	Soft Link	Soft Link			DI	
4	Incoming Breaker Open Status	Soft Link	Soft Link			DI	
5	Incoming Feeder Line Voltage	Soft Link	Soft Link	AI			
6	Incoming Feeder Line Current	Soft Link	Soft Link	AI			
7	Incoming Feeder Volt Ampere (VA)	Soft Link	Soft Link	AI			
8	Incoming Feeder Frequency (Hz)	Soft Link	Soft Link	AI			
9	Incoming Feeder Power Factor (PF)	Soft Link	Soft Link	AI			
10	Incoming Feeder Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
11	Incoming Feeder Volt Ampere Reactive (VAR)	Soft Link	Soft Link	AI			
12	Control Supply Status	VFC	24 VDC			1	
13	Incoming Breaker Open Command	230VAC	VFC				1
14	Incoming Breaker Close Command	230VAC	VFC				1
15	~~Incoming Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
16	~~Tie Breaker Close Status - ASS1 TO ASS3~~	~~VFC~~	~~24 VDC~~				
17	~~Tie Breaker Open Status - ASS1 TO ASS3~~	~~VFC~~	~~24 VDC~~				
	MDB-170/270 Incoming Circuit Breaker from DB 290						
1	Incoming Breaker Local/Remote Status	VFC	24 VDC			1	
2	Incoming Breaker Trip Alarm	Soft Link	Soft Link			DI	
3	Incoming Breaker Close Status	Soft Link	Soft Link			DI	
4	Incoming Breaker Open Status	Soft Link	Soft Link			DI	
5	Incoming Feeder Line Voltage	Soft Link	Soft Link	AI			
6	Incoming Feeder Line Current	Soft Link	Soft Link	AI			
7	Incoming Feeder Volt Ampere (VA)	Soft Link	Soft Link	AI			
8	Incoming Feeder Frequency (Hz)	Soft Link	Soft Link	AI			
9	Incoming Feeder Power Factor (PF)	Soft Link	Soft Link	AI			
10	Incoming Feeder Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
11	Incoming Feeder Volt Ampere Reactive (VAR)	Soft Link	Soft Link	AI			
12	Control Supply Status	VFC	24 VDC			1	
13	Incoming Breaker Open Command	230VAC	VFC				1
14	Incoming Breaker Close Command	230VAC	VFC				1
	MDB-170/270 Bus-Coupler						
1	Bus-coupler Breaker Close Status	VFC	24 VDC			1	

S. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	SIGNAL TYPE			
				AI	AO	DI	DO
2	Bus-coupler Breaker Open Status	VFC	24 VDC			1	
	Chiller-1 Outgoing C.B. CH-401						
1	Outgoing Breaker Local/Remote Status	VFC	24 VDC			1	
2	Outgoing Breaker Open Command	230 VAC	VFC				1
3	Outgoing Breaker Close Command	230 VAC	VFC				1
4	Outgoing Breaker Trip Alarm	VFC	24 VDC			1	
5	Outgoing Breaker Close Status	VFC	24 VDC			1	
6	Outgoing Breaker Open Status	VFC	24 VDC			1	
7	Outgoing Feeder Line Current	4-20 mA	4-20 mA	1			
8	Outgoing Feeder Kwh	Soft Link	Soft Link	AI			
9	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
10	~~Outgoing Feeder Line Voltage~~	~~4-20 mA~~	~~4-20 mA~~				
	Chiller-2 Outgoing C.B. CH-402						
1	Outgoing Breaker Local/Remote Status	VFC	24 VDC			1	
2	Outgoing Breaker Open Command	230 VAC	VFC				1
3	Outgoing Breaker Close Command	230 VAC	VFC				1
4	Outgoing Breaker Trip Alarm	VFC	24 VDC			1	
5	Outgoing Breaker Close Status	VFC	24 VDC			1	
6	Outgoing Breaker Open Status	VFC	24 VDC			1	
7	Outgoing Feeder Line Current	4-20 mA	4-20 mA	1			
8	Outgoing Feeder Kwh	Soft Link	Soft Link	AI			
9	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
10	~~Outgoing Feeder Line Voltage~~	~~4-20 mA~~	~~4-20 mA~~				
	Chiller-3 Outgoing C.B. CH-403						
1	Outgoing Breaker Local/Remote Status	VFC	24 VDC			1	
2	Outgoing Breaker Open Command	230 VAC	VFC				1
3	Outgoing Breaker Close Command	230 VAC	VFC				1
4	Outgoing Breaker Trip Alarm	VFC	24 VDC			1	
5	Outgoing Breaker Close Status	VFC	24 VDC			1	
6	Outgoing Breaker Open Status	VFC	24 VDC			1	
7	Outgoing Feeder Line Current	4-20 mA	4-20 mA	1			
8	Outgoing Feeder Kwh	Soft Link	Soft Link	AI			
9	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
10	~~Outgoing Feeder Line Voltage~~	~~4-20 mA~~	~~4-20 mA~~				
	Chiller-4 Outgoing C.B. CH-404						
1	Outgoing Breaker Local/Remote Status	VFC	24 VDC			1	
2	Outgoing Breaker Open Command	230 VAC	VFC				1
3	Outgoing Breaker Close Command	230 VAC	VFC				1
4	Outgoing Breaker Trip Alarm	VFC	24 VDC			1	
5	Outgoing Breaker Close Status	VFC	24 VDC			1	
6	Outgoing Breaker Open Status	VFC	24 VDC			1	
7	Outgoing Feeder Line Current	4-20 mA	4-20 mA	1			
8	Outgoing Feeder Kwh	Soft Link	Soft Link	AI			
9	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
10	~~Outgoing Feeder Line Voltage~~	~~4-20 mA~~	~~4-20 mA~~				
	CHILLED WATER PRIMARY PUMP -1 OUTGOING C.B. PCHWP-401						
1	Outgoing Breaker Trip Alarm	VFC	24 VDC			1	
2	Outgoing Breaker Close Status	VFC	24 VDC			1	
3	Outgoing Breaker Open Status	VFC	24 VDC			1	
4	Outgoing Feeder Line Current	4-20 mA	4-20 mA	1			
5	Outgoing Feeder Kwh	Soft Link	Soft Link	AI			
6	~~Outgoing Breaker Local/Remote Status~~	~~VFC~~	~~24 VDC~~				
7	~~Outgoing Breaker Open / Close Command~~	~~230 VAC~~	~~VFC~~				
8	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
9	~~Outgoing Feeder Line Voltage~~	~~4-20 mA~~	~~4-20 mA~~				
	CHILLED WATER PRIMARY PUMP -2 OUTGOING C.B. PCHWP-402						
1	Outgoing Breaker Trip Alarm	VFC	24 VDC			1	
2	Outgoing Breaker Close Status	VFC	24 VDC			1	
3	Outgoing Breaker Open Status	VFC	24 VDC			1	
4	Outgoing Feeder Line Current	4-20 mA	4-20 mA	1			
5	Outgoing Feeder Kwh	Soft Link	Soft Link	AI			
6	~~Outgoing Breaker Local/Remote Status~~	~~VFC~~	~~24 VDC~~				
7	~~Outgoing Breaker Open / Close Command~~	~~230 VAC~~	~~VFC~~				
8	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
9	~~Outgoing Feeder Line Voltage~~	~~4-20 mA~~	~~4-20 mA~~				
	CHILLED WATER PRIMARY PUMP -3 OUTGOING C.B. PCHWP-403						
1	Outgoing Breaker Trip Alarm	VFC	24 VDC			1	
2	Outgoing Breaker Close Status	VFC	24 VDC			1	

S. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	SIGNAL TYPE			
				AI	AO	DI	DO
3	Outgoing Breaker Open Status	VFC	24 VDC			1	
4	Outgoing Feeder Line Current	4-20 mA	4-20 mA	1			
5	Outgoing Feeder Kwh	Soft Link	Soft Link	AI			
6	~~Outgoing Breaker Local/Remote Status~~	~~VFC~~	~~24 VDC~~				
7	~~Outgoing Breaker Open / Close Command~~	~~230 VAC~~	~~VFC~~				
8	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
9	~~Outgoing Feeder Line Voltage~~	~~4-20 mA~~	~~4-20 mA~~				
	CHILLED WATER PRIMARY PUMP -4 OUTGOING C.B. PCHWP-404						
1	Outgoing Breaker Trip Alarm	VFC	24 VDC			1	
2	Outgoing Breaker Close Status	VFC	24 VDC			1	
3	Outgoing Breaker Open Status	VFC	24 VDC			1	
4	Outgoing Feeder Line Current	4-20 mA	4-20 mA	1			
5	Outgoing Feeder Kwh	Soft Link	Soft Link	AI			
6	~~Outgoing Breaker Local/Remote Status~~	~~VFC~~	~~24 VDC~~				
7	~~Outgoing Breaker Open / Close Command~~	~~230 VAC~~	~~VFC~~				
8	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
9	~~Outgoing Feeder Line Voltage~~	~~4-20 mA~~	~~4-20 mA~~				
	CHILLED WATER PRIMARY PUMP -5 OUTGOING C.B. PCHWP-405						
1	Outgoing Breaker Trip Alarm	VFC	24 VDC			1	
2	Outgoing Breaker Close Status	VFC	24 VDC			1	
3	Outgoing Breaker Open Status	VFC	24 VDC			1	
4	Outgoing Feeder Line Current	4-20 mA	4-20 mA	1			
5	Outgoing Feeder Kwh	Soft Link	Soft Link	AI			
6	~~Outgoing Breaker Local/Remote Status~~	~~VFC~~	~~24 VDC~~				
7	~~Outgoing Breaker Open / Close Command~~	~~230 VAC~~	~~VFC~~				
8	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
9	~~Outgoing Feeder Line Voltage~~	~~4-20 mA~~	~~4-20 mA~~				
	CHILLED WATER SECONDARY PUMP -1 OUTGOING C.B. SCHWP-401						
1	Outgoing Breaker Trip Alarm	VFC	24 VDC			1	
2	Outgoing Breaker Close Status	VFC	24 VDC			1	
3	Outgoing Breaker Open Status	VFC	24 VDC			1	
4	Outgoing Feeder Line Current	4-20 mA	4-20 mA	1			
5	Outgoing Feeder Kwh	Soft Link	Soft Link	AI			
6	~~Outgoing Breaker Local/Remote Status~~	~~VFC~~	~~24 VDC~~				
7	~~Outgoing Breaker Open / Close Command~~	~~230 VAC~~	~~VFC~~				
8	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
9	~~Outgoing Feeder Line Voltage~~	~~4-20 mA~~	~~4-20 mA~~				
	CHILLED WATER SECONDARY PUMP -2 OUTGOING C.B. SCHWP-402						
1	Outgoing Breaker Trip Alarm	VFC	24 VDC			1	
2	Outgoing Breaker Close Status	VFC	24 VDC			1	
3	Outgoing Breaker Open Status	VFC	24 VDC			1	
4	Outgoing Feeder Line Current	4-20 mA	4-20 mA	1			
5	Outgoing Feeder Kwh	Soft Link	Soft Link	AI			
6	~~Outgoing Breaker Local/Remote Status~~	~~VFC~~	~~24 VDC~~				
7	~~Outgoing Breaker Open / Close Command~~	~~230 VAC~~	~~VFC~~				
8	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
9	~~Outgoing Feeder Line Voltage~~	~~4-20 mA~~	~~4-20 mA~~				
	CHILLED WATER SECONDARY PUMP -3 OUTGOING C.B. SCHWP-403						
1	Outgoing Breaker Trip Alarm	VFC	24 VDC			1	
2	Outgoing Breaker Close Status	VFC	24 VDC			1	
3	Outgoing Breaker Open Status	VFC	24 VDC			1	
4	Outgoing Feeder Line Current	4-20 mA	4-20 mA	1			
5	Outgoing Feeder Kwh	Soft Link	Soft Link	AI			
6	~~Outgoing Breaker Local/Remote Status~~	~~VFC~~	~~24 VDC~~				
7	~~Outgoing Breaker Open / Close Command~~	~~230 VAC~~	~~VFC~~				
8	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
9	~~Outgoing Feeder Line Voltage~~	~~4-20 mA~~	~~4-20 mA~~				
	CHILLED WATER SECONDARY PUMP -4 OUTGOING C.B. SCHWP-404						
1	Outgoing Breaker Trip Alarm	VFC	24 VDC			1	
2	Outgoing Breaker Close Status	VFC	24 VDC			1	
3	Outgoing Breaker Open Status	VFC	24 VDC			1	
4	Outgoing Feeder Line Current	4-20 mA	4-20 mA	1			
5	Outgoing Feeder Kwh	Soft Link	Soft Link	AI			
6	~~Outgoing Breaker Local/Remote Status~~	~~VFC~~	~~24 VDC~~				
7	~~Outgoing Breaker Open / Close Command~~	~~230 VAC~~	~~VFC~~				
8	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
9	~~Outgoing Feeder Line Voltage~~	~~4-20 mA~~	~~4-20 mA~~				
	CONDENSING WATER PUMP-1 OUTGOING C.B. CDWP-401						

S. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	SIGNAL TYPE			
				AI	AO	DI	DO
1	Outgoing Breaker Trip Alarm	VFC	24 VDC			1	
2	Outgoing Breaker Close Status	VFC	24 VDC			1	
3	Outgoing Breaker Open Status	VFC	24 VDC			1	
4	Outgoing Feeder Line Current	4-20 mA	4-20 mA	1			
5	Outgoing Feeder Kwh	Soft Link	Soft Link	AI			
6	~~Outgoing Breaker Local/Remote Status~~	~~VFC~~	~~24 VDC~~				
7	~~Outgoing Breaker Open / Close Command~~	~~230 VAC~~	~~VFC~~				
8	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
9	~~Outgoing Feeder Line Voltage~~	~~4-20 mA~~	~~4-20 mA~~				
	CONDENSING WATER PUMP-2 OUTGOING C.B. CDWP-402						
1	Outgoing Breaker Trip Alarm	VFC	24 VDC			1	
2	Outgoing Breaker Close Status	VFC	24 VDC			1	
3	Outgoing Breaker Open Status	VFC	24 VDC			1	
4	Outgoing Feeder Line Current	4-20 mA	4-20 mA	1			
5	Outgoing Feeder Kwh	Soft Link	Soft Link	AI			
6	~~Outgoing Breaker Local/Remote Status~~	~~VFC~~	~~24 VDC~~				
7	~~Outgoing Breaker Open / Close Command~~	~~230 VAC~~	~~VFC~~				
8	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
9	~~Outgoing Feeder Line Voltage~~	~~4-20 mA~~	~~4-20 mA~~				
	CONDENSING WATER PUMP-3 OUTGOING C.B. CDWP-403						
1	Outgoing Breaker Trip Alarm	VFC	24 VDC			1	
2	Outgoing Breaker Close Status	VFC	24 VDC			1	
3	Outgoing Breaker Open Status	VFC	24 VDC			1	
4	Outgoing Feeder Line Current	4-20 mA	4-20 mA	1			
5	Outgoing Feeder Kwh	Soft Link	Soft Link	AI			
6	~~Outgoing Breaker Local/Remote Status~~	~~VFC~~	~~24 VDC~~				
7	~~Outgoing Breaker Open / Close Command~~	~~230 VAC~~	~~VFC~~				
8	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
9	~~Outgoing Feeder Line Voltage~~	~~4-20 mA~~	~~4-20 mA~~				
	CONDENSING WATER PUMP-4 OUTGOING C.B. CDWP-404						
1	Outgoing Breaker Trip Alarm	VFC	24 VDC			1	
2	Outgoing Breaker Close Status	VFC	24 VDC			1	
3	Outgoing Breaker Open Status	VFC	24 VDC			1	
4	Outgoing Feeder Line Current	4-20 mA	4-20 mA	1			
5	Outgoing Feeder Kwh	Soft Link	Soft Link	AI			
6	~~Outgoing Breaker Local/Remote Status~~	~~VFC~~	~~24 VDC~~				
7	~~Outgoing Breaker Open / Close Command~~	~~230 VAC~~	~~VFC~~				
8	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
9	~~Outgoing Feeder Line Voltage~~	~~4-20 mA~~	~~4-20 mA~~				
	CONDENSING WATER PUMP-5 OUTGOING C.B. CDWP-405						
1	Outgoing Breaker Trip Alarm	VFC	24 VDC			1	
2	Outgoing Breaker Close Status	VFC	24 VDC			1	
3	Outgoing Breaker Open Status	VFC	24 VDC			1	
4	Outgoing Feeder Line Current	4-20 mA	4-20 mA	1			
5	Outgoing Feeder Kwh	Soft Link	Soft Link	AI			
6	~~Outgoing Breaker Local/Remote Status~~	~~VFC~~	~~24 VDC~~				
7	~~Outgoing Breaker Open / Close Command~~	~~230 VAC~~	~~VFC~~				
8	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
9	~~Outgoing Feeder Line Voltage~~	~~4-20 mA~~	~~4-20 mA~~				
	CONDENSING WATER PUMP-6 OUTGOING C.B. CDWP-406						
1	Outgoing Breaker Trip Alarm	VFC	24 VDC			1	
2	Outgoing Breaker Close Status	VFC	24 VDC			1	
3	Outgoing Breaker Open Status	VFC	24 VDC			1	
4	Outgoing Feeder Line Current	4-20 mA	4-20 mA	1			
5	Outgoing Feeder Kwh	Soft Link	Soft Link	AI			
6	~~Outgoing Breaker Local/Remote Status~~	~~VFC~~	~~24 VDC~~				
7	~~Outgoing Breaker Open / Close Command~~	~~230 VAC~~	~~VFC~~				
8	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
9	~~Outgoing Feeder Line Voltage~~	~~4-20 mA~~	~~4-20 mA~~				
	COOLING TOWER-1 ,FAN-1 OUTGOING C.B. CT-601						
1	Outgoing Breaker Trip Alarm	VFC	24 VDC			1	
2	Outgoing Breaker Close Status	VFC	24 VDC			1	
3	Outgoing Breaker Open Status	VFC	24 VDC			1	
4	Outgoing Feeder Line Current	4-20 mA	4-20 mA	1			
5	Outgoing Feeder Kwh	Soft Link	Soft Link	AI			
6	~~Outgoing Breaker Local/Remote Status~~	~~VFC~~	~~24 VDC~~				
7	~~Outgoing Breaker Open / Close Command~~	~~230 VAC~~	~~VFC~~				
8	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				

S. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	SIGNAL TYPE			
				AI	AO	DI	DO
9	~~Outgoing Feeder Line Voltage~~	~~4-20 mA~~	~~4-20 mA~~				
	COOLING TOWER-1 ,FAN-2 OUTGOING C.B.CT-601						
1	Outgoing Breaker Trip Alarm	VFC	24 VDC			1	
2	Outgoing Breaker Close Status	VFC	24 VDC			1	
3	Outgoing Breaker Open Status	VFC	24 VDC			1	
4	Outgoing Feeder Line Current	4-20 mA	4-20 mA	1			
5	Outgoing Feeder Kwh	Soft Link	Soft Link	AI			
6	~~Outgoing Breaker Local/Remote Status~~	~~VFC~~	~~24 VDC~~				
7	~~Outgoing Breaker Open / Close Command~~	~~230 VAC~~	~~VFC~~				
8	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
9	~~Outgoing Feeder Line Voltage~~	~~4-20 mA~~	~~4-20 mA~~				
	COOLING TOWER-2 ,FAN-1 OUTGOING C.B.CT-602						
1	Outgoing Breaker Trip Alarm	VFC	24 VDC			1	
2	Outgoing Breaker Close Status	VFC	24 VDC			1	
3	Outgoing Breaker Open Status	VFC	24 VDC			1	
4	Outgoing Feeder Line Current	4-20 mA	4-20 mA	1			
5	Outgoing Feeder Kwh	Soft Link	Soft Link	AI			
6	~~Outgoing Breaker Local/Remote Status~~	~~VFC~~	~~24 VDC~~				
7	~~Outgoing Breaker Open / Close Command~~	~~230 VAC~~	~~VFC~~				
8	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
9	~~Outgoing Feeder Line Voltage~~	~~4-20 mA~~	~~4-20 mA~~				
	COOLING TOWER-2 ,FAN-2 OUTGOING C.B.CT-602						
1	Outgoing Breaker Trip Alarm	VFC	24 VDC			1	
2	Outgoing Breaker Close Status	VFC	24 VDC			1	
3	Outgoing Breaker Open Status	VFC	24 VDC			1	
4	Outgoing Feeder Line Current	4-20 mA	4-20 mA	1			
5	Outgoing Feeder Kwh	Soft Link	Soft Link	AI			
6	~~Outgoing Breaker Local/Remote Status~~	~~VFC~~	~~24 VDC~~				
7	~~Outgoing Breaker Open / Close Command~~	~~230 VAC~~	~~VFC~~				
8	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
9	~~Outgoing Feeder Line Voltage~~	~~4-20 mA~~	~~4-20 mA~~				
	COOLING TOWER-3 ,FAN-1 OUTGOING C.B.CT-603						
1	Outgoing Breaker Trip Alarm	VFC	24 VDC			1	
2	Outgoing Breaker Close Status	VFC	24 VDC			1	
3	Outgoing Breaker Open Status	VFC	24 VDC			1	
4	Outgoing Feeder Line Current	4-20 mA	4-20 mA	1			
5	Outgoing Feeder Kwh	Soft Link	Soft Link	AI			
6	~~Outgoing Breaker Local/Remote Status~~	~~VFC~~	~~24 VDC~~				
7	~~Outgoing Breaker Open / Close Command~~	~~230 VAC~~	~~VFC~~				
8	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
9	~~Outgoing Feeder Line Voltage~~	~~4-20 mA~~	~~4-20 mA~~				
	COOLING TOWER-3 ,FAN-2 OUTGOING C.B.CT-603						
1	Outgoing Breaker Trip Alarm	VFC	24 VDC			1	
2	Outgoing Breaker Close Status	VFC	24 VDC			1	
3	Outgoing Breaker Open Status	VFC	24 VDC			1	
4	Outgoing Feeder Line Current	4-20 mA	4-20 mA	1			
5	Outgoing Feeder Kwh	Soft Link	Soft Link	AI			
6	~~Outgoing Breaker Local/Remote Status~~	~~VFC~~	~~24 VDC~~				
7	~~Outgoing Breaker Open / Close Command~~	~~230 VAC~~	~~VFC~~				
8	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
9	~~Outgoing Feeder Line Voltage~~	~~4-20 mA~~	~~4-20 mA~~				
	COOLING TOWER-4 ,FAN-1 OUTGOING C.B.CT-604						
1	Outgoing Breaker Trip Alarm	VFC	24 VDC			1	
2	Outgoing Breaker Close Status	VFC	24 VDC			1	
3	Outgoing Breaker Open Status	VFC	24 VDC			1	
4	Outgoing Feeder Line Current	4-20 mA	4-20 mA	1			
5	Outgoing Feeder Kwh	Soft Link	Soft Link	AI			
6	~~Outgoing Breaker Local/Remote Status~~	~~VFC~~	~~24 VDC~~				
7	~~Outgoing Breaker Open / Close Command~~	~~230 VAC~~	~~VFC~~				
8	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
9	~~Outgoing Feeder Line Voltage~~	~~4-20 mA~~	~~4-20 mA~~				
	COOLING TOWER-4 ,FAN-2 OUTGOING C.B.CT-604						
1	Outgoing Breaker Trip Alarm	VFC	24 VDC			1	
2	Outgoing Breaker Close Status	VFC	24 VDC			1	
3	Outgoing Breaker Open Status	VFC	24 VDC			1	
4	Outgoing Feeder Line Current	4-20 mA	4-20 mA	1			
5	Outgoing Feeder Kwh	Soft Link	Soft Link	AI			

S. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	SIGNAL TYPE			
				AI	AO	DI	DO
6	~~Outgoing Breaker Local/Remote Status~~	~~VFC~~	~~24 VDC~~				
7	~~Outgoing Breaker Open / Close Command~~	~~230 VAC~~	~~VFC~~				
8	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
9	~~Outgoing Feeder Line Voltage~~	~~4-20 mA~~	~~4-20 mA~~				
	Spare Cooling Tower, Fan-1 Outgoing CB						
1	Outgoing Breaker Trip Alarm	VFC	24 VDC			1	
2	Outgoing Breaker Close Status	VFC	24 VDC			1	
3	Outgoing Breaker Open Status	VFC	24 VDC			1	
4	Outgoing Feeder Line Current	4-20 mA	4-20 mA	1			
5	Outgoing Feeder Kwh	Soft Link	Soft Link	AI			
	Spare Cooling Tower, Fan-2 Outgoing CB						
1	Outgoing Breaker Trip Alarm	VFC	24 VDC			1	
2	Outgoing Breaker Close Status	VFC	24 VDC			1	
3	Outgoing Breaker Open Status	VFC	24 VDC			1	
4	Outgoing Feeder Line Current	4-20 mA	4-20 mA	1			
5	Outgoing Feeder Kwh	Soft Link	Soft Link	AI			
	Capacitor Panel-1, DB-CAP-170/270 Incoming C.B. (ACB)						
1	Outgoing Breaker Trip Alarm	VFC	24 VDC			1	
2	Outgoing Breaker Close Status	VFC	24 VDC			1	
3	Outgoing Breaker Open Status	VFC	24 VDC			1	
4	Outgoing Feeder Line Voltage	4-20mA	4-20mA	1			
5	Outgoing Feeder Line Current	4-20mA	4-20mA	1			
6	Capacitor Bank Failure/APFC relay Alarm	VFC	24 VDC			1	
7	~~Capacitor Bank Off Status~~	VFC	24 VDC				
8	Capacitor Bank OverTemp Alarm	VFC	24 VDC			1	
9	APFC Data	Soft Link	Soft Link	AI			
10	~~Outgoing Feeder Protection Relay Operation Status~~	24 VDC					
11	~~Outgoing Breaker Local/Remote Status~~	VFC	24 VDC				
12	~~Outgoing Breaker Open Command~~	230 V	VFC				
13	~~Outgoing Breaker Close Command~~	230 V	VFC				
	Capacitor Panel-1, CP 170/270- Outgoing CB						
1	Outgoing Breaker Trip Alarm	VFC	24 VDC			1	
2	Outgoing Breaker Close Status	VFC	24 VDC			1	
3	Outgoing Breaker Open Status	VFC	24 VDC			1	
4	Outgoing Feeder Line Voltage	4-20mA	4-20mA	1			
5	Outgoing Feeder Line Current	4-20mA	4-20mA	1			
6	~~Capacitor Bank Failure/APFC relay Alarm~~	~~VFC~~	~~24 VDC~~				
7	~~Capacitor Bank Off Status~~	~~VFC~~	~~24 VDC~~				
8	~~Capacitor Bank OverTemp Alarm~~	~~VFC~~	~~24 VDC~~				
9	~~APFC Data~~	~~Soft Link~~	~~Soft Link~~				
10	~~Outgoing Feeder Protection Relay Operation Status~~	24 VDC					
11	~~Outgoing Breaker Local/Remote Status~~	VFC	24 VDC				
12	~~Outgoing Breaker Open Command~~	230 V	VFC				
13	~~Outgoing Breaker Close Command~~	230 V	VFC				
	Capacitor Panel-2, DB-CAP-170/270 Incoming C.B. (ACB)						
1	Outgoing Breaker Trip Alarm	VFC	24 VDC			1	
2	Outgoing Breaker Close Status	VFC	24 VDC			1	
3	Outgoing Breaker Open Status	VFC	24 VDC			1	
4	Outgoing Feeder Line Voltage	4-20mA	4-20mA	1			
5	Outgoing Feeder Line Current	4-20mA	4-20mA	1			
6	Capacitor Bank Failure/APFC relay Alarm	VFC	24 VDC			1	
7	~~Capacitor Bank Off Status~~	VFC	24 VDC				
8	Capacitor Bank OverTemp Alarm	VFC	24 VDC			1	
9	APFC Data	Soft Link	Soft Link	AI			
10	~~Outgoing Feeder Protection Relay Operation Status~~	24 VDC					
11	~~Outgoing Breaker Local/Remote Status~~	VFC	24 VDC				
12	~~Outgoing Breaker Open Command~~	230 V	VFC				
13	~~Outgoing Breaker Close Command~~	230 V	VFC				
	Capacitor Panel-2, CP 170/270- Outgoing CB						
1	Outgoing Breaker Trip Alarm	VFC	24 VDC			1	
2	Outgoing Breaker Close Status	VFC	24 VDC			1	
3	Outgoing Breaker Open Status	VFC	24 VDC			1	
4	Outgoing Feeder Line Voltage	4-20mA	4-20mA	1			
5	Outgoing Feeder Line Current	4-20mA	4-20mA	1			

S. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	SIGNAL TYPE AI	AO	DI	DO
6	~~Capacitor Bank Failure/APFC relay Alarm~~	~~VFC~~	~~24 VDC~~				
7	~~Capacitor Bank Off Status~~	~~VFC~~	~~24 VDC~~				
8	~~Capacitor Bank OverTemp Alarm~~	~~VFC~~	~~24 VDC~~				
9	~~APFC Data~~	~~Soft Link~~	~~Soft Link~~				
10	~~Outgoing Feeder Protection Relay Operation Status~~	24 VDC					
11	~~Outgoing Breaker Local/Remote Status~~	VFC	24 VDC				
12	~~Outgoing Breaker Open Command~~	230 V	VFC				
13	~~Outgoing Breaker Close Command~~	230 V	VFC				
	DB-Pump room Panel Outgoing Circuit Breaker (WTP)						
1	Outgoing Breaker Trip Alarm	VFC	24 VDC			1	
2	Outgoing Breaker Close Status	VFC	24 VDC			1	
3	Outgoing Breaker Open Status	VFC	24 VDC			1	
4	Outgoing Feeder Line Current	4-20 mA	4-20 mA	1			
5	~~Outgoing Feeder Kwh~~	~~Soft Link~~	~~Soft Link~~				
6	~~Outgoing Breaker Local/Remote Status~~	~~VFC~~	~~24 VDC~~				
7	~~Outgoing Breaker Open / Close Command~~	~~230 VAC~~	~~VFC~~				
8	~~Outgoing Feeder Line Voltage~~	~~4-20 mA~~	~~4-20 mA~~				
	JW-DB-330 Incomer Circuit Breaker						
1	~~Incoming Breaker Local/Remote Status~~						
2	Incoming Breaker Trip Alarm	VFC	24 VDC			1	
3	Incoming Breaker Close Status	VFC	24 VDC			1	
4	Incoming Breaker Open Status	VFC	24 VDC			1	
5	Mains Incoming Voltage	4-20mA	4-20mA	1			
6	Incoming Feeder Line Current	4-20mA	4-20mA	1			
7	Incoming Feeder Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
8	~~Feeder Protection Relay Operation Status~~						
	DB-330 Outgoing Circuit Breaker						
1	Outgoing Breaker Trip Alarm	VFC	24 VDC			1	
2	Outgoing Breaker Close Status	VFC	24 VDC			1	
3	Outgoing Breaker Open Status	VFC	24 VDC			1	
4	Outgoing Feeder Line Current	4-20 mA	4-20 mA	1			
5	~~Outgoing Feeder Kwh~~	~~Soft Link~~	~~Soft Link~~				
6	~~Outgoing Breaker Local/Remote Status~~	~~VFC~~	~~24 VDC~~				
7	~~Outgoing Breaker Open / Close Command~~	~~230 VAC~~	~~VFC~~				
8	~~Outgoing Feeder Line Voltage~~	~~4-20 mA~~	~~4-20 mA~~				
	LDB-AB Outgoing Circuit Breaker						
1	Outgoing Breaker Trip Alarm	VFC	24 VDC			1	
2	Outgoing Breaker Close Status	VFC	24 VDC			1	
3	Outgoing Breaker Open Status	VFC	24 VDC			1	
4	Outgoing Feeder Line Current	4-20 mA	4-20 mA	1			
5	~~Outgoing Feeder Kwh~~	~~Soft Link~~	~~Soft Link~~				
6	~~Outgoing Breaker Local/Remote Status~~	~~VFC~~	~~24 VDC~~				
7	~~Outgoing Breaker Open / Close Command~~	~~230 VAC~~	~~VFC~~				
8	~~Outgoing Feeder Line Voltage~~	~~4-20 mA~~	~~4-20 mA~~				
	Spare Outgoing Circuit Breaker-01						
1	Outgoing Breaker Trip Alarm	VFC	24 VDC			1	
2	Outgoing Breaker Close Status	VFC	24 VDC			1	
3	Outgoing Breaker Open Status	VFC	24 VDC			1	
4	Outgoing Feeder Line Current	4-20 mA	4-20 mA	1			
5	~~Outgoing Feeder Kwh~~	~~Soft Link~~	~~Soft Link~~				
6	~~Outgoing Breaker Local/Remote Status~~	~~VFC~~	~~24 VDC~~				
7	~~Outgoing Breaker Open / Close Command~~	~~230 VAC~~	~~VFC~~				
8	~~Outgoing Feeder Line Voltage~~	~~4-20 mA~~	~~4-20 mA~~				
	Spare Outgoing Circuit Breaker-02						
1	Outgoing Breaker Trip Alarm	VFC	24 VDC			1	
2	Outgoing Breaker Close Status	VFC	24 VDC			1	
3	Outgoing Breaker Open Status	VFC	24 VDC			1	
4	Outgoing Feeder Line Current	4-20 mA	4-20 mA	1			
5	~~Outgoing Feeder Kwh~~	~~Soft Link~~	~~Soft Link~~				
6	~~Outgoing Breaker Local/Remote Status~~	~~VFC~~	~~24 VDC~~				
7	~~Outgoing Breaker Open / Close Command~~	~~230 VAC~~	~~VFC~~				
8	~~Outgoing Feeder Line Voltage~~	~~4-20 mA~~	~~4-20 mA~~				
	Backup To Fire Pump DB-160 CB from MDB-170/270						
1	Outgoing Breaker Trip Alarm	VFC	24 VDC			1	
2	Outgoing Breaker Close Status	VFC	24 VDC			1	
3	Outgoing Breaker Open Status	VFC	24 VDC			1	

S. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	SIGNAL TYPE			
				AI	AO	DI	DO
4	Outgoing Feeder Line Current	4-20 mA	4-20 mA	1			
5	~~Outgoing Feeder Kwh~~	~~Soft Link~~	~~Soft Link~~				
6	~~Outgoing Breaker Local/Remote Status~~	~~VFC~~	~~24 VDC~~				
7	~~Outgoing Breaker Open / Close Command~~	~~230 VAC~~	~~VFC~~				
8	~~Outgoing Feeder Line Voltage~~	~~4-20 mA~~	~~4-20 mA~~				
	Main Air Scrolled Chiller Outgoing Circuit Breaker (From DB 170/270)						
1	Outgoing Breaker Trip Alarm	VFC	24 VDC			1	
2	Outgoing Breaker Close Status	VFC	24 VDC			1	
3	Outgoing Breaker Open Status	VFC	24 VDC			1	
4	Outgoing Feeder Line Current	4-20 mA	4-20 mA	1			
5	~~Outgoing Breaker Local/Remote Status~~	~~VFC~~	~~24 VDC~~				
6	~~Outgoing Breaker Open Command~~	~~230 VAC~~	~~VFC~~				
7	~~Outgoing Breaker Close Command~~	~~230 VAC~~	~~VFC~~				
8	~~Outgoing Feeder Kwh~~	~~Soft Link~~	~~Soft Link~~				
	FROM DB-330						
	Ventilation Exhaust Fan,AB VEF-401						
1	Local/Remote Switch Status	VFC	24 VDC			1	
2	On/Off Command	230 VAC	VFC				1
3	Air Flow status	VFC	24 VDC			1	
4	Motor Running Feedback	VFC	24 VDC			1	
5	Emergency Stop Button Position	VFC	24 VDC			1	
6	Trip	VFC	24 VDC			1	
7	FID Damper Open Position	VFC	24 VDC			1	
8	FID Damper Close Position	VFC	24 VDC			1	
9	Motor Current	4-20 mA	4-20 mA	1			
10	Energy consumption Kwh	Soft Link	Soft Link	AI			
	Ventilation Exhaust Fan,AB VEF-402						
1	Local/Remote Switch Status	VFC	24 VDC			1	
2	On/Off Command	230 VAC	VFC				1
3	Air Flow status	VFC	24 VDC			1	
4	Motor Running Feedback	VFC	24 VDC			1	
5	Emergency Stop Button Position	VFC	24 VDC			1	
6	Trip	VFC	24 VDC			1	
7	FID Damper Open Position	VFC	24 VDC			1	
8	FID Damper Close Position	VFC	24 VDC			1	
9	Motor Current	4-20 mA	4-20 mA	1			
10	Energy consumption Kwh	Soft Link	Soft Link	AI			
	Spare Ventilation Exhaust Fan, SPARE-VEF						
1	Local/Remote Switch Status	VFC	24 VDC			1	
2	On/Off Command	230 VAC	VFC				1
3	Motor Running Feedback	VFC	24 VDC			1	
4	Emergency Stop Button Position	VFC	24 VDC			1	
5	Trip	VFC	24 VDC			1	
6	FID Damper Open Position	VFC	24 VDC			1	
7	FID Damper Close Position	VFC	24 VDC			1	
8	Motor Current	4-20mA	4-20mA	1			
9	Energy consumption Kwh	Soft Link	Soft Link	AI			
	Ventilation Exhaust Fan,AB VEF-501						
1	Local/Remote Switch Status	VFC	24 VDC			1	
2	On/Off Command	230 VAC	VFC				1
3	Air Flow status	VFC	24 VDC			1	
4	Motor Running Feedback	VFC	24 VDC			1	
5	Emergency Stop Button Position	VFC	24 VDC			1	
6	Trip	VFC	24 VDC			1	
7	FID Damper Open Position	VFC	24 VDC			1	
8	FID Damper Close Position	VFC	24 VDC			1	
9	Motor Current	4-20 mA	4-20 mA	1			
10	Energy consumption Kwh	Soft Link	Soft Link	AI			
	Ventilation Exhaust Fan,AB VEF-502						
1	Local/Remote Switch Status	VFC	24 VDC			1	
2	On/Off Command	230 VAC	VFC				1
3	Air Flow status	VFC	24 VDC			1	
4	Motor Running Feedback	VFC	24 VDC			1	
5	Emergency Stop Button Position	VFC	24 VDC			1	
6	Trip	VFC	24 VDC			1	
7	FID Damper Open Position	VFC	24 VDC			1	
8	FID Damper Close Position	VFC	24 VDC			1	

S. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	SIGNAL TYPE			
				AI	AO	DI	DO
9	Motor Current	4-20 mA	4-20 mA	1			
10	Energy consumption Kwh	Soft Link	Soft Link	AI			
	Ventilation Supply Fan, VSF-401						
1	Local/Remote Switch Status	VFC	24 VDC			1	
2	On/Off Command	230 VAC	VFC				1
3	Motor Running Feedback	VFC	24 VDC			1	
4	Air Flow status	VFC	24 VDC			1	
5	Emergency Stop Button Position	VFC	24 VDC			1	
6	Trip	VFC	24 VDC			1	
7	FID Damper Open Position	VFC	24 VDC			1	
8	FID Damper Close Position	VFC	24 VDC			1	
9	Motor Current	4-20mA	4-20mA	1			
10	Energy consumption Kwh	Soft Link	Soft Link	AI			
	Ventilation Supply Fan, VSF-402						
1	Local/Remote Switch Status	VFC	24 VDC			1	
2	On/Off Command	230 VAC	VFC				1
3	Motor Running Feedback	VFC	24 VDC			1	
4	Air Flow status	VFC	24 VDC			1	
5	Emergency Stop Button Position	VFC	24 VDC			1	
6	Trip	VFC	24 VDC			1	
7	FID Damper Open Position	VFC	24 VDC			1	
8	FID Damper Close Position	VFC	24 VDC			1	
9	Motor Current	4-20mA	4-20mA	1			
10	Energy consumption Kwh	Soft Link	Soft Link	AI			
	Air Scrolled Chiller Panel						
	Air Scrolled Chiller Incoming Circuit Breaker from DB-170/270/290						
1	ATS/PLC Auto/Manual Status	Soft Link	Soft Link			DI	
2	Primary Breaker Trip status	Soft Link	Soft Link			DI	
3	Primary Breaker Open status	Soft Link	Soft Link			DI	
4	Primary Breaker Close status	Soft Link	Soft Link			DI	
5	Secondary Breaker Trip Status	Soft Link	Soft Link			DI	
6	Secondary Breaker Open Status	Soft Link	Soft Link			DI	
7	Secondary Breaker Close Status	Soft Link	Soft Link			DI	
8	Incoming Feeder Line Voltage	Soft Link	Soft Link	AI			
9	Incoming Feeder Line Current	Soft Link	Soft Link	AI			
10	Incoming Feeder Volt Ampere (VA)	Soft Link	Soft Link	AI			
11	Incoming Feeder Frequency (Hz)	Soft Link	Soft Link	AI			
12	Incoming Feeder Power Factor (PF)	Soft Link	Soft Link	AI			
13	Incoming Feeder Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
14	Incoming Feeder Volt Ampere Reactive (VAR)	Soft Link	Soft Link	AI			
15	Dual Supply Status	VFC	24 VDC			1	
16	Main supply off alarm	VFC	24 VDC			1	
	Air Scrolled Chiller-1 Outgoing Circuit Breaker ACC-601						
1	Outgoing Breaker Trip Alarm	VFC	24 VDC			1	
2	Outgoing Breaker Close Status	VFC	24 VDC			1	
3	Outgoing Breaker Open Status	VFC	24 VDC			1	
4	Outgoing Feeder Line Current	4-20 mA	4-20 mA	1			
5	Outgoing Feeder Kwh	Soft Link	Soft Link	AI			
	Air Scrolled Chiller-2 Outgoing Circuit Breaker JW-ACC-602						
1	Outgoing Breaker Trip Alarm	VFC	24 VDC			1	
2	Outgoing Breaker Close Status	VFC	24 VDC			1	
3	Outgoing Breaker Open Status	VFC	24 VDC			1	
4	Outgoing Feeder Line Current	4-20 mA	4-20 mA	1			
5	Outgoing Feeder Kwh	Soft Link	Soft Link	AI			
	Air Scrolled Chiller CHWP-1 Outgoing Circuit Breaker ACHWP-401						
1	Outgoing Breaker Trip Alarm	VFC	24 VDC			1	
2	Outgoing Breaker Close Status	VFC	24 VDC			1	
3	Outgoing Breaker Open Status	VFC	24 VDC			1	
4	Outgoing Feeder Line Current	4-20 mA	4-20 mA	1			
5	Outgoing Feeder Kwh	Soft Link	Soft Link	AI			
	Air Scrolled Chiller CHWP-1 Outgoing Circuit Breaker ACHWP-402						

S. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	SIGNAL TYPE			
				AI	AO	DI	DO
1	Outgoing Breaker Trip Alarm	VFC	24 VDC			1	
2	Outgoing Breaker Close Status	VFC	24 VDC			1	
3	Outgoing Breaker Open Status	VFC	24 VDC			1	
4	Outgoing Feeder Line Current	4-20 mA	4-20 mA	1			
5	Outgoing Feeder Kwh	Soft Link	Soft Link	AI			
	Refrigerant Leak Detector						
1	Refrigerant Leak Status	VFC	24 VDC			1	
2	~~Condenser Water Treatment Unit Fault~~	~~VFC~~	~~24 VDC~~				
	Outside Air Temperature and Relative Humidity						
1	Outside Air temperature	4-20 mA	4-20 mA	1			
2	Outside R.H.	4-20 mA	4-20 mA	1			
	Chemical Dosing System						
1	Chemical Tank Low Level Alarm	VFC	24 VDC			1	
2	Dosing Pump Status	VFC	24 VDC			1	
	CPM						
	Chilled Water Pump Primary ,PCHWP-401						
1	On/off Command	Soft Link	Soft Link			DI	
2	Flow Status	Soft Link	Soft Link			DI	
3	Running Feedback	Soft Link	Soft Link			DI	
4	Local/Remote Switch Status	Soft Link	Soft Link			DI	
5	Emergency Stop Button Position	Soft Link	Soft Link			DI	
6	Trip	Soft Link	Soft Link			DI	
7	Motor Current	Soft Link	Soft Link	AI			
	Chilled Water Pump Primary ,PCHWP-402						
1	On/off Command	Soft Link	Soft Link			DI	
2	Flow Status	Soft Link	Soft Link			DI	
3	Running Feedback	Soft Link	Soft Link			DI	
4	Local/Remote Switch Status	Soft Link	Soft Link			DI	
5	Emergency Stop Button Position	Soft Link	Soft Link			DI	
6	Trip	Soft Link	Soft Link			DI	
7	Motor Current	Soft Link	Soft Link	AI			
	Chilled Water Pump Primary ,PCHWP-403						
1	On/off Command	Soft Link	Soft Link			DI	
2	Flow Status	Soft Link	Soft Link			DI	
3	Running Feedback	Soft Link	Soft Link			DI	
4	Local/Remote Switch Status	Soft Link	Soft Link			DI	
5	Emergency Stop Button Position	Soft Link	Soft Link			DI	
6	Trip	Soft Link	Soft Link			DI	
7	Motor Current	Soft Link	Soft Link	AI			
	Chilled Water Pump Primary ,PCHWP-404						
1	On/off Command	Soft Link	Soft Link			DI	
2	Flow Status	Soft Link	Soft Link			DI	
3	Running Feedback	Soft Link	Soft Link			DI	
4	Local/Remote Switch Status	Soft Link	Soft Link			DI	
5	Emergency Stop Button Position	Soft Link	Soft Link			DI	
6	Trip	Soft Link	Soft Link			DI	
7	Motor Current	Soft Link	Soft Link	AI			
	Chilled Water Pump Primary ,PCHWP-405						
1	On/off Command	Soft Link	Soft Link			DI	
2	Flow Status	Soft Link	Soft Link			DI	
3	Running Feedback	Soft Link	Soft Link			DI	
4	Local/Remote Switch Status	Soft Link	Soft Link			DI	
5	Emergency Stop Button Position	Soft Link	Soft Link			DI	
6	Trip	Soft Link	Soft Link			DI	
7	Motor Current	Soft Link	Soft Link	AI			
	Chilled Water Pump Secondary,SCHWP-401						
1	On/off Command	Soft Link	Soft Link			DI	
2	Flow Status	Soft Link	Soft Link			DI	
3	Running Feedback	Soft Link	Soft Link			DI	
4	Local/Remote Switch Status	Soft Link	Soft Link			DI	
5	Emergency Stop Button Position	Soft Link	Soft Link			DI	
6	Trip	Soft Link	Soft Link			DI	
7	Motor Current	Soft Link	Soft Link	AI			
	Chilled Water Pump Secondary,SCHWP-402						
1	On/off Command	Soft Link	Soft Link			DI	
2	Flow Status	Soft Link	Soft Link			DI	
3	Running Feedback	Soft Link	Soft Link			DI	
4	Local/Remote Switch Status	Soft Link	Soft Link			DI	
5	Emergency Stop Button Position	Soft Link	Soft Link			DI	
6	Trip	Soft Link	Soft Link			DI	
7	Motor Current	Soft Link	Soft Link	AI			

S. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	SIGNAL TYPE			
				AI	AO	DI	DO
	Chilled Water Pump Secondary,SCHWP-403						
1	On/off Command	Soft Link	Soft Link			DI	
2	Flow Status	Soft Link	Soft Link			DI	
3	Running Feedback	Soft Link	Soft Link			DI	
4	Local/Remote Switch Status	Soft Link	Soft Link			DI	
5	Emergency Stop Button Position	Soft Link	Soft Link			DI	
6	Trip	Soft Link	Soft Link			DI	
7	Motor Current	Soft Link	Soft Link	AI			
	Chilled Water Pump Secondary,SCHWP-404						
1	On/off Command	Soft Link	Soft Link			DI	
2	Flow Status	Soft Link	Soft Link			DI	
3	Running Feedback	Soft Link	Soft Link			DI	
4	Local/Remote Switch Status	Soft Link	Soft Link			DI	
5	Emergency Stop Button Position	Soft Link	Soft Link			DI	
6	Trip	Soft Link	Soft Link			DI	
7	Motor Current	Soft Link	Soft Link	AI			
	Condenser Water Pump, CDWP-401						
1	On/off Command	Soft Link	Soft Link			DI	
2	Flow Status	Soft Link	Soft Link			DI	
3	Running Feedback	Soft Link	Soft Link			DI	
4	Local/Remote Switch Status	Soft Link	Soft Link			DI	
5	Emergency Stop Button Position	Soft Link	Soft Link			DI	
6	Trip	Soft Link	Soft Link			DI	
7	Motor Current	Soft Link	Soft Link	AI			
	Condenser Water Pump, CDWP-402						
1	On/off Command	Soft Link	Soft Link			DI	
2	Flow Status	Soft Link	Soft Link			DI	
3	Running Feedback	Soft Link	Soft Link			DI	
4	Local/Remote Switch Status	Soft Link	Soft Link			DI	
5	Emergency Stop Button Position	Soft Link	Soft Link			DI	
6	Trip	Soft Link	Soft Link			DI	
7	Motor Current	Soft Link	Soft Link	AI			
	Condenser Water Pump, CDWP-403						
1	On/off Command	Soft Link	Soft Link			DI	
2	Flow Status	Soft Link	Soft Link			DI	
3	Running Feedback	Soft Link	Soft Link			DI	
4	Local/Remote Switch Status	Soft Link	Soft Link			DI	
5	Emergency Stop Button Position	Soft Link	Soft Link			DI	
6	Trip	Soft Link	Soft Link			DI	
7	Motor Current	Soft Link	Soft Link	AI			
	Condenser Water Pump, CDWP-404						
1	On/off Command	Soft Link	Soft Link			DI	
2	Flow Status	Soft Link	Soft Link			DI	
3	Running Feedback	Soft Link	Soft Link			DI	
4	Local/Remote Switch Status	Soft Link	Soft Link			DI	
5	Emergency Stop Button Position	Soft Link	Soft Link			DI	
6	Trip	Soft Link	Soft Link			DI	
7	Motor Current	Soft Link	Soft Link	AI			
	Condenser Water Pump, CDWP-405						
1	On/off Command	Soft Link	Soft Link			DI	
2	Flow Status	Soft Link	Soft Link			DI	
3	Running Feedback	Soft Link	Soft Link			DI	
4	Local/Remote Switch Status	Soft Link	Soft Link			DI	
5	Emergency Stop Button Position	Soft Link	Soft Link			DI	
6	Trip	Soft Link	Soft Link			DI	
7	Motor Current	Soft Link	Soft Link	AI			
	Condenser Water Pump, CDWP-406						
1	On/off Command	Soft Link	Soft Link			DI	
2	Flow Status	Soft Link	Soft Link			DI	
3	Running Feedback	Soft Link	Soft Link			DI	
4	Local/Remote Switch Status	Soft Link	Soft Link			DI	
5	Emergency Stop Button Position	Soft Link	Soft Link			DI	
6	Trip	Soft Link	Soft Link			DI	
7	Motor Current	Soft Link	Soft Link	AI			
	Cooling Tower, CT-601						
1	Motor # 1 On/off	Soft Link	Soft Link			DI	
2	Motor # 1 Running Feedback	Soft Link	Soft Link			DI	
3	Motor # 1 Local/Remote Switch Status	Soft Link	Soft Link			DI	
4	Motor # 1 Emergency Stop Button Position	Soft Link	Soft Link			DI	
5	Motor # 1 Trip	Soft Link	Soft Link			DI	
6	Motor # 1 Current	Soft Link	Soft Link	AI			
7	Motor # 1 Vibration	Soft Link	Soft Link			DI	

S. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	SIGNAL TYPE			
				AI	AO	DI	DO
8	Motor # 2 On/off	Soft Link	Soft Link			DI	
9	Motor # 2 Running Feedback	Soft Link	Soft Link			DI	
10	Motor # 2 Local/Remote Switch Status	Soft Link	Soft Link			DI	
11	Motor # 2 Emergency Stop Button Position	Soft Link	Soft Link			DI	
12	Motor # 2 Trip	Soft Link	Soft Link			DI	
13	Motor # 2 Current	Soft Link	Soft Link	AI			
14	Motor # 2 Vibration	Soft Link	Soft Link			DI	
	Cooling Tower, CT-602						
1	Motor # 1 On/off	Soft Link	Soft Link			DI	
2	Motor # 1 Running Feedback	Soft Link	Soft Link			DI	
3	Motor # 1 Local/Remote Switch Status	Soft Link	Soft Link			DI	
4	Motor # 1 Emergency Stop Button Position	Soft Link	Soft Link			DI	
5	Motor # 1 Trip	Soft Link	Soft Link			DI	
6	Motor # 1 Current	Soft Link	Soft Link	AI			
7	Motor # 1 Vibration	Soft Link	Soft Link			DI	
8	Motor # 2 On/off	Soft Link	Soft Link			DI	
9	Motor # 2 Running Feedback	Soft Link	Soft Link			DI	
10	Motor # 2 Local/Remote Switch Status	Soft Link	Soft Link			DI	
11	Motor # 2 Emergency Stop Button Position	Soft Link	Soft Link			DI	
12	Motor # 2 Trip	Soft Link	Soft Link			DI	
13	Motor # 2 Current	Soft Link	Soft Link	AI			
14	Motor # 2 Vibration	Soft Link	Soft Link			DI	
	Cooling Tower, CT-603						
1	Motor # 1 On/off	Soft Link	Soft Link			DI	
2	Motor # 1 Running Feedback	Soft Link	Soft Link			DI	
3	Motor # 1 Local/Remote Switch Status	Soft Link	Soft Link			DI	
4	Motor # 1 Emergency Stop Button Position	Soft Link	Soft Link			DI	
5	Motor # 1 Trip	Soft Link	Soft Link			DI	
6	Motor # 1 Current	Soft Link	Soft Link	AI			
7	Motor # 1 Vibration	Soft Link	Soft Link			DI	
8	Motor # 2 On/off	Soft Link	Soft Link			DI	
9	Motor # 2 Running Feedback	Soft Link	Soft Link			DI	
10	Motor # 2 Local/Remote Switch Status	Soft Link	Soft Link			DI	
11	Motor # 2 Emergency Stop Button Position	Soft Link	Soft Link			DI	
12	Motor # 2 Trip	Soft Link	Soft Link			DI	
13	Motor # 2 Current	Soft Link	Soft Link	AI			
14	Motor # 2 Vibration	Soft Link	Soft Link			DI	
	Cooling Tower, CT-604						
1	Motor # 1 On/off	Soft Link	Soft Link			DI	
2	Motor # 1 Running Feedback	Soft Link	Soft Link			DI	
3	Motor # 1 Local/Remote Switch Status	Soft Link	Soft Link			DI	
4	Motor # 1 Emergency Stop Button Position	Soft Link	Soft Link			DI	
5	Motor # 1 Trip	Soft Link	Soft Link			DI	
6	Motor # 1 Current	Soft Link	Soft Link	AI			
7	Motor # 1 Vibration	Soft Link	Soft Link			DI	
8	Motor # 2 On/off	Soft Link	Soft Link			DI	
9	Motor # 2 Running Feedback	Soft Link	Soft Link			DI	
10	Motor # 2 Local/Remote Switch Status	Soft Link	Soft Link			DI	
11	Motor # 2 Emergency Stop Button Position	Soft Link	Soft Link			DI	
12	Motor # 2 Trip	Soft Link	Soft Link			DI	
13	Motor # 2 Current	Soft Link	Soft Link	AI			
14	Motor # 2 Vibration	Soft Link	Soft Link			DI	
	Temperature Monitoring						
1	Common Chiller header Supply Temperature	Soft Link	Soft Link	AI			
2	Common Chiller header Return Temperature	Soft Link	Soft Link	AI			
3	Cooling Tower Common Outlet Temperature	Soft Link	Soft Link	AI			
4	Cooling Tower Common Inlet Temperature	Soft Link	Soft Link	AI			
	Chiller, CH-401						
1	Chiller On/Off Command	Soft Link	Soft Link			DI	
2	Chiller Running Feedback	Soft Link	Soft Link			DI	
3	Chiller Local/Remote Position	Soft Link	Soft Link			DI	
4	Chiller Current Low/High Alarm	Soft Link	Soft Link			DI	
5	Chiller Trip Alarm	Soft Link	Soft Link			DI	
6	Chiller Refrigerant Pressure Low/High Alarm	Soft Link	Soft Link			DI	
7	Chiller Temperature High Alarm	Soft Link	Soft Link			DI	
8	Chiller Water Low Flow Alarm	Soft Link	Soft Link			DI	
9	Condenser Temperature High Alarm	Soft Link	Soft Link			DI	
10	Condenser Water Low Flow Alarm	Soft Link	Soft Link			DI	
	Chiller, CH-402						
1	Chiller On/Off Command	Soft Link	Soft Link			DI	
2	Chiller Running Feedback	Soft Link	Soft Link			DI	
3	Chiller Local/Remote Position	Soft Link	Soft Link			DI	
4	Chiller Current Low/High Alarm	Soft Link	Soft Link			DI	

S. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	SIGNAL TYPE			
				AI	AO	DI	DO
5	Chiller Trip Alarm	Soft Link	Soft Link			DI	
6	Chiller Refrigerant Pressure Low/High Alarm	Soft Link	Soft Link			DI	
7	Chiller Temperature High Alarm	Soft Link	Soft Link			DI	
8	Chiller Water Low Flow Alarm	Soft Link	Soft Link			DI	
9	Condenser Temperature High Alarm	Soft Link	Soft Link			DI	
10	Condenser Water Low Flow Alarm	Soft Link	Soft Link			DI	
	Chiller, CH-403						
1	Chiller On/Off Command	Soft Link	Soft Link			DI	
2	Chiller Running Feedback	Soft Link	Soft Link			DI	
3	Chiller Local/Remote Position	Soft Link	Soft Link			DI	
4	Chiller Current Low/High Alarm	Soft Link	Soft Link			DI	
5	Chiller Trip Alarm	Soft Link	Soft Link			DI	
6	Chiller Refrigerant Pressure Low/High Alarm	Soft Link	Soft Link			DI	
7	Chiller Temperature High Alarm	Soft Link	Soft Link			DI	
9	Chiller Water Low Flow Alarm	Soft Link	Soft Link			DI	
8	Condenser Temperature High Alarm	Soft Link	Soft Link			DI	
10	Condenser Water Low Flow Alarm	Soft Link	Soft Link			DI	
	Chiller, CH-404						
1	Chiller On/Off Command	Soft Link	Soft Link			DI	
2	Chiller Running Feedback	Soft Link	Soft Link			DI	
3	Chiller Local/Remote Position	Soft Link	Soft Link			DI	
4	Chiller Current Low/High Alarm	Soft Link	Soft Link			DI	
5	Chiller Trip Alarm	Soft Link	Soft Link			DI	
6	Chiller Refrigerant Pressure Low/High Alarm	Soft Link	Soft Link			DI	
7	Chiller Temperature High Alarm	Soft Link	Soft Link			DI	
9	Chiller Water Low Flow Alarm	Soft Link	Soft Link			DI	
8	Condenser Temperature High Alarm	Soft Link	Soft Link			DI	
10	Condenser Water Low Flow Alarm	Soft Link	Soft Link			DI	
	Cooling Tower-01 Level Monitoring						
1	Sump 1 Low Level	Soft Link	Soft Link			DI	
2	Sump 1 High Level	Soft Link	Soft Link			DI	
3	Sump 2 Low Level	Soft Link	Soft Link			DI	
4	Sump 2 High Level	Soft Link	Soft Link			DI	
	Cooling Tower-02 Level Monitoring						
1	Sump 1 Low Level	Soft Link	Soft Link			DI	
2	Sump 1 High Level	Soft Link	Soft Link			DI	
3	Sump 2 Low Level	Soft Link	Soft Link			DI	
4	Sump 2 High Level	Soft Link	Soft Link			DI	
	Cooling Tower-03 Level Monitoring						
1	Sump 1 Low Level	Soft Link	Soft Link			DI	
2	Sump 1 High Level	Soft Link	Soft Link			DI	
3	Sump 2 Low Level	Soft Link	Soft Link			DI	
4	Sump 2 High Level	Soft Link	Soft Link			DI	
	Cooling Tower Bleeder						
1	MOV open status	Soft Link	Soft Link			DI	
2	MOV Close status	Soft Link	Soft Link			DI	
3	MOV Open command	Soft Link	Soft Link			DI	
4	MOV Close command	Soft Link	Soft Link			DI	
5	MOV Local/Remote Status	Soft Link	Soft Link			DI	
	MOV for CHILLER SYSTEM(13 Nos)						
1	MOV open status	Soft Link	Soft Link			DI	
2	MOV Close status	Soft Link	Soft Link			DI	
3	MOV Open command	Soft Link	Soft Link			DI	
4	MOV Close command	Soft Link	Soft Link			DI	
5	MOV Local/Remote Status	Soft Link	Soft Link			DI	
	MOV for Air Scrolled CHILLER SYSTEM (6 Nos)						
1	MOV open status	Soft Link	Soft Link			DI	
2	MOV Close status	Soft Link	Soft Link			DI	
3	MOV Open command	Soft Link	Soft Link			DI	
4	MOV Close command	Soft Link	Soft Link			DI	
5	MOV Local/Remote Status	Soft Link	Soft Link			DI	
	Air Scroll Chilled Water Pump ACHWP-401						
1	On/off Command	Soft Link	Soft Link			DI	
2	Flow Status	Soft Link	Soft Link			DI	
3	Running Feedback	Soft Link	Soft Link			DI	
4	Local/Remote Switch Status	Soft Link	Soft Link			DI	
5	Emergency Stop Button Position	Soft Link	Soft Link			DI	
6	Trip	Soft Link	Soft Link			DI	
7	Motor Current	Soft Link	Soft Link	AI			
	Air Scroll Chilled Water Pump ACHWP-402						
1	On/off Command	Soft Link	Soft Link			DI	
2	Flow Status	Soft Link	Soft Link			DI	

S. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	SIGNAL TYPE AI	AO	DI	DO
3	Running Feedback	Soft Link	Soft Link			DI	
4	Local/Remote Switch Status	Soft Link	Soft Link			DI	
5	Emergency Stop Button Position	Soft Link	Soft Link			DI	
6	Trip	Soft Link	Soft Link			DI	
7	Motor Current	Soft Link	Soft Link	AI			
	Air Scrolled Chiller, ACH-401						
1	Sys-1 and 2 On/Off Command	Soft Link	Soft Link			DI	
2	Sys-1 Running Feedback	Soft Link	Soft Link			DI	
3	Sys-2 Running Feedback	Soft Link	Soft Link			DI	
4	Sys Local/Remote Position	Soft Link	Soft Link			DI	
5	Chiller Current Low/High Alarm	Soft Link	Soft Link			DI	
6	Sys-1 Trip/ Fault Alarm Alarm	Soft Link	Soft Link			DI	
7	Sys-2 Trip/ Fault Alarm Alarm	Soft Link	Soft Link			DI	
8	Chiller Refrigerant Pressure Low/High Alarm	Soft Link	Soft Link			DI	
9	Chiller Temperature High Alarm	Soft Link	Soft Link			DI	
10	Chiller Water Low Flow Alarm	Soft Link	Soft Link			DI	
11	Condenser Temperature High Alarm	Soft Link	Soft Link			DI	
	Air Scrolled Chiller, ACH-402						
1	Sys-1 and 2 On/Off Command	Soft Link	Soft Link			DI	
2	Sys-1 Running Feedback	Soft Link	Soft Link			DI	
3	Sys-2 Running Feedback	Soft Link	Soft Link			DI	
4	Sys Local/Remote Position	Soft Link	Soft Link			DI	
5	Chiller Current Low/High Alarm	Soft Link	Soft Link			DI	
6	Sys-1 Trip/ Fault Alarm Alarm	Soft Link	Soft Link			DI	
7	Sys-2 Trip/ Fault Alarm Alarm	Soft Link	Soft Link			DI	
8	Chiller Refrigerant Pressure Low/High Alarm	Soft Link	Soft Link			DI	
9	Chiller Temperature High Alarm	Soft Link	Soft Link			DI	
10	Chiller Water Low Flow Alarm	Soft Link	Soft Link			DI	
11	Condenser Temperature High Alarm	Soft Link	Soft Link			DI	
1	Water Flow In line For Chiller1	Soft Link	Soft Link	AI			
2	Water Flow In line For Chiller2	Soft Link	Soft Link	AI			
3	Water Flow In line For Chiller3	Soft Link	Soft Link	AI			
4	Water Flow In line For CT 1	Soft Link	Soft Link	AI			
5	Water Flow In line For CT 2	Soft Link	Soft Link	AI			
6	Water Flow In line For CT 3	Soft Link	Soft Link	AI			
7	Water Flow In line For Makup for CT	Soft Link	Soft Link	AI			
		Hard Signal		59	0	206	23
		Soft Signal		114	0	353	0

Sr. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	SIGNAL TYPE AI	AO	DI	DO
	MDB-100 Incoming Circuit Breaker						
1	Incoming Breaker Local/Auto Status	VFC	24 VDC			1	
2	Incoming Breaker Trip Alarm	Soft Link	Soft Link			DI	
3	Incoming Breaker Close Status	Soft Link	Soft Link			DI	
4	Incoming Breaker Open Status	Soft Link	Soft Link			DI	
5	Incoming Feeder Line Voltage	Soft Link	Soft Link	AI			
6	Incoming Feeder Line Current	Soft Link	Soft Link	AI			
7	Incoming Feeder Volt Ampere (VA)	Soft Link	Soft Link	AI			
8	Incoming Feeder Frequency (Hz)	Soft Link	Soft Link	AI			
9	Incoming Feeder Power Factor (PF)	Soft Link	Soft Link	AI			
10	Incoming Feeder Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
11	Incoming Feeder Volt Ampere Reactive (VAR)	Soft Link	Soft Link	AI			
12	Tie Breaker Close Status - ASS1 TO ASS2(ACB-3)	Soft Link	Soft Link			DI	
13	Tie Breaker Open Status - ASS1 TO ASS2(ACB-3)	Soft Link	Soft Link			DI	
14	Bus-coupler Breaker Close Status(ACB-5)	Soft Link	Soft Link			DI	
15	Bus-coupler Breaker Open Status(ACB-5)	Soft Link	Soft Link			DI	
16	Maximum demand	Soft Link	Soft Link	AI			
17	Control Supply Healthy Status	VFC	24 VDC			1	
18	Emergency stop status	VFC	24 VDC			1	
19	~~Incoming Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
20	~~Incoming Breaker Open/CLOSE Command~~						
21	~~Incoming Breaker Close Command~~						
	Pumps/Escalator DB-150 Outgoing C.B. (ACB)						
1	Outgoing Breaker Local/Remote Status	VFC	24 VDC			1	
2	Outgoing Breaker Open Command	230 VAC	VFC				1
3	Outgoing Breaker Close Command	230 VAC	VFC				1
4	Outgoing Breaker Trip Alarm	Soft Link	Soft Link			DI	
5	Outgoing Breaker Close Status	Soft Link	Soft Link			DI	
6	Outgoing Breaker Open Status	Soft Link	Soft Link			DI	
7	Outgoing Feeder Line Current	Soft Link	Soft Link	AI			
8	Energy consumption Kwh	Soft Link	Soft Link	AI			
9	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
10	~~Outgoing Feeder Line Voltage~~	Soft Link	Soft Link				
	Spare Feeder-1(ACB)						
1	Outgoing Breaker Local/Remote Status	VFC	24 VDC			1	
2	Outgoing Breaker Open Command	230 VAC	VFC				1
3	Outgoing Breaker Close Command	230 VAC	VFC				1
4	Outgoing Breaker Trip Alarm	Soft Link	Soft Link			DI	
5	Outgoing Breaker Close Status	Soft Link	Soft Link			DI	
6	Outgoing Breaker Open Status	Soft Link	Soft Link			DI	
7	Outgoing Feeder Line Current	Soft Link	Soft Link	AI			
8	Energy consumption Kwh	Soft Link	Soft Link	AI			
9	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
10	~~Outgoing Feeder Line Voltage~~	Soft Link	Soft Link				
	Spare Feeder-2(ACB)						
1	Outgoing Breaker Local/Remote Status	VFC	24 VDC			1	
2	Outgoing Breaker Open Command	230 VAC	VFC				1
3	Outgoing Breaker Close Command	230 VAC	VFC				1
4	Outgoing Breaker Trip Alarm	Soft Link	Soft Link			DI	
5	Outgoing Breaker Close Status	Soft Link	Soft Link			DI	
6	Outgoing Breaker Open Status	Soft Link	Soft Link			DI	
7	Outgoing Feeder Line Current	Soft Link	Soft Link	AI			
8	Energy consumption Kwh	Soft Link	Soft Link	AI			
9	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
10	~~Outgoing Feeder Line Voltage~~	Soft Link	Soft Link				
	Spare Feeder-3 (MCCB)						
1	Outgoing Breaker Local/Remote Status	VFC	24 VDC			1	
2	Outgoing Breaker Open Command	230 VAC	VFC				1
3	Outgoing Breaker Close Command	230 VAC	VFC				1
4	Outgoing Breaker Trip Alarm	Soft Link	Soft Link			DI	
5	Outgoing Breaker Close Status	Soft Link	Soft Link			DI	
6	Outgoing Breaker Open Status	Soft Link	Soft Link			DI	

Sr. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	SIGNAL TYPE			
				AI	AO	DI	DO
7	Outgoing Feeder Line Current	Soft Link	Soft Link	AI			
8	Energy consumption Kwh	Soft Link	Soft Link	AI			
9	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
10	~~Outgoing Feeder Line Voltage~~	Soft Link	Soft Link				
	Spare Feeder-4 (MCCB)						
1	Outgoing Breaker Local/Remote Status	VFC	24 VDC			1	
2	Outgoing Breaker Open Command	230 VAC	VFC				1
3	Outgoing Breaker Close Command	230 VAC	VFC				1
4	Outgoing Breaker Trip Alarm	Soft Link	Soft Link			DI	
5	Outgoing Breaker Close Status	Soft Link	Soft Link			DI	
6	Outgoing Breaker Open Status	Soft Link	Soft Link			DI	
7	Outgoing Feeder Line Current	Soft Link	Soft Link	AI			
8	Energy consumption Kwh	Soft Link	Soft Link	AI			
9	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
10	~~Outgoing Feeder Line Voltage~~	Soft Link	Soft Link				
	Spare Feeder-5 (MCCB)						
1	Outgoing Breaker Local/Remote Status	VFC	24 VDC			1	
2	Outgoing Breaker Open Command	230 VAC	VFC				1
3	Outgoing Breaker Close Command	230 VAC	VFC				1
4	Outgoing Breaker Trip Alarm	Soft Link	Soft Link			DI	
5	Outgoing Breaker Close Status	Soft Link	Soft Link			DI	
6	Outgoing Breaker Open Status	Soft Link	Soft Link			DI	
7	Outgoing Feeder Line Current	Soft Link	Soft Link	AI			
8	Energy consumption Kwh	Soft Link	Soft Link	AI			
9	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
10	~~Outgoing Feeder Line Voltage~~	Soft Link	Soft Link				
	Tunnel Ventilation Fans MCC, DB-140 Outgoing C.B. (ACB)						
1	Outgoing Breaker Local/Remote Status	VFC	24 VDC			1	
2	Outgoing Breaker Open Command	230 VAC	VFC				1
3	Outgoing Breaker Close Command	230 VAC	VFC				1
4	Outgoing Breaker Trip Alarm	Soft Link	Soft Link			DI	
5	Outgoing Breaker Close Status	Soft Link	Soft Link			DI	
6	Outgoing Breaker Open Status	Soft Link	Soft Link			DI	
7	Outgoing Feeder Line Current	Soft Link	Soft Link	AI			
8	Energy consumption Kwh	Soft Link	Soft Link	AI			
9	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
10	~~Outgoing Feeder Line Voltage~~	Soft Link	Soft Link				
	Backup To TVF MCC, DB-240 Outgoing C.B. (ACB)						
1	Outgoing Breaker Local/Remote Status	VFC	24 VDC			1	
2	Outgoing Breaker Open Command	230 VAC	VFC				1
3	Outgoing Breaker Close Command	230 VAC	VFC				1
4	Outgoing Breaker Trip Alarm	Soft Link	Soft Link			DI	
5	Outgoing Breaker Close Status	Soft Link	Soft Link			DI	
6	Outgoing Breaker Open Status	Soft Link	Soft Link			DI	
7	Outgoing Feeder Line Current	Soft Link	Soft Link	AI			
8	Energy consumption Kwh	Soft Link	Soft Link	AI			
9	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
10	~~Outgoing Feeder Line Voltage~~	Soft Link	Soft Link				
	AHU & TEF MCC, DB-130A Outgoing C.B. (ACB)						
1	Outgoing Breaker Local/Remote Status	VFC	24 VDC			1	
2	Outgoing Breaker Open Command	230 VAC	VFC				1
3	Outgoing Breaker Close Command	230 VAC	VFC				1
4	Outgoing Breaker Trip Alarm	Soft Link	Soft Link			DI	
5	Outgoing Breaker Close Status	Soft Link	Soft Link			DI	
6	Outgoing Breaker Open Status	Soft Link	Soft Link			DI	
7	Outgoing Feeder Line Current	Soft Link	Soft Link	AI			
8	Energy consumption Kwh	Soft Link	Soft Link	AI			
9	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
10	~~Outgoing Feeder Line Voltage~~	Soft Link	Soft Link				
	AHU & TEF MCC, DB-130B Outgoing C.B. (ACB)						
1	Outgoing Breaker Local/Remote Status	VFC	24 VDC			1	
2	Outgoing Breaker Open Command	230 VAC	VFC				1

Sr. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	SIGNAL TYPE			
				AI	AO	DI	DO
3	Outgoing Breaker Close Command	230 VAC	VFC				1
4	Outgoing Breaker Trip Alarm	Soft Link	Soft Link			DI	
5	Outgoing Breaker Close Status	Soft Link	Soft Link			DI	
6	Outgoing Breaker Open Status	Soft Link	Soft Link			DI	
7	Outgoing Feeder Line Current	Soft Link	Soft Link	AI			
8	Energy consumption Kwh	Soft Link	Soft Link	AI			
9	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
10	~~Outgoing Feeder Line Voltage~~	Soft Link	Soft Link				
	Back up to AHU & TEF MCC, DB-230 Outgoing C.B. (ACB)						
1	Outgoing Breaker Local/Remote Status	VFC	24 VDC			1	
2	Outgoing Breaker Open Command	230 VAC	VFC				1
3	Outgoing Breaker Close Command	230 VAC	VFC				1
4	Outgoing Breaker Trip Alarm	Soft Link	Soft Link			DI	
5	Outgoing Breaker Close Status	Soft Link	Soft Link			DI	
6	Outgoing Breaker Open Status	Soft Link	Soft Link			DI	
7	Outgoing Feeder Line Current	Soft Link	Soft Link	AI			
8	Energy consumption Kwh	Soft Link	Soft Link	AI			
9	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
10	~~Outgoing Feeder Line Voltage~~	Soft Link	Soft Link				
	To DB 170/270 -Chiller Outgoing Circuit Breaker (ACB)						
1	Outgoing Breaker Local/Remote Status	VFC	24 VDC			1	
2	Outgoing Breaker Open Command	230 VAC	VFC				1
3	Outgoing Breaker Close Command	230 VAC	VFC				1
4	Outgoing Breaker Trip Alarm	Soft Link	Soft Link			DI	
5	Outgoing Breaker Close Status	Soft Link	Soft Link			DI	
6	Outgoing Breaker Open Status	Soft Link	Soft Link			DI	
7	Outgoing Feeder Line Current	Soft Link	Soft Link	AI			
8	Energy consumption Kwh	Soft Link	Soft Link	AI			
9	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
10	~~Outgoing Feeder Line Voltage~~	Soft Link	Soft Link				
	Lighting Supply, DB-120, Outgoing Ckt Breaker (MCCB)						
1	Outgoing Breaker Local/Remote Status	VFC	24 VDC			1	
2	Outgoing Breaker Open Command	230 VAC	VFC				1
3	Outgoing Breaker Close Command	230 VAC	VFC				1
4	Outgoing Breaker Trip Alarm	Soft Link	Soft Link			DI	
5	Outgoing Breaker Close Status	Soft Link	Soft Link			DI	
6	Outgoing Breaker Open Status	Soft Link	Soft Link			DI	
7	Outgoing Feeder Line Current	Soft Link	Soft Link	AI			
8	Energy consumption Kwh	Soft Link	Soft Link	AI			
9	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
10	~~Outgoing Feeder Line Voltage~~	Soft Link	Soft Link				
	Small Power Supply, DB-110 Outgoing Ckt Breaker (MCCB)						
1	Outgoing Breaker Local/Remote Status	VFC	24 VDC			1	
2	Outgoing Breaker Open Command	230 VAC	VFC				1
3	Outgoing Breaker Close Command	230 VAC	VFC				1
4	Outgoing Breaker Trip Alarm	Soft Link	Soft Link			DI	
5	Outgoing Breaker Close Status	Soft Link	Soft Link			DI	
6	Outgoing Breaker Open Status	Soft Link	Soft Link			DI	
7	Outgoing Feeder Line Current	Soft Link	Soft Link	AI			
8	Energy consumption Kwh	Soft Link	Soft Link	AI			
9	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
10	~~Outgoing Feeder Line Voltage~~	Soft Link	Soft Link				
	Capacitor Panel, DB-CAP-100 Incoming C.B. (ACB)						
1	Outgoing Breaker Trip Alarm	VFC	24 VDC			1	
2	Outgoing Breaker Close Status	VFC	24 VDC			1	
3	Outgoing Breaker Open Status	VFC	24 VDC			1	
4	Outgoing Feeder Line Voltage	4-20mA	4-20mA	1			
5	Outgoing Feeder Line Current	4-20mA	4-20mA	1			
6	Capacitor Bank Failure/APFC relay Alarm	VFC	24 VDC			1	
7	~~Capacitor Bank Off Status~~	VFC	24 VDC				
8	Capacitor Bank OverTemp Alarm	VFC	24 VDC			1	

Sr. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	SIGNAL TYPE			
				AI	AO	DI	DO
9	APFC Data	Soft Link	Soft Link	AI			
10	~~Outgoing Feeder Protection Relay Operation Status~~	24 VDC					
11	~~Outgoing Breaker Local/Remote Status~~	VFC	24 VDC				
12	~~Outgoing Breaker Open Command~~	230 V	VFC				
13	~~Outgoing Breaker Close Command~~	230 V	VFC				
	Capacitor Panel, DB-CAP-100 Outgoing C.B. (ACB)						
1	Outgoing Breaker Trip Alarm	VFC	24 VDC			1	
2	Outgoing Breaker Close Status	VFC	24 VDC			1	
3	Outgoing Breaker Open Status	VFC	24 VDC			1	
4	Outgoing Feeder Line Voltage	4-20mA	4-20mA	1			
5	Outgoing Feeder Line Current	4-20mA	4-20mA	1			
6	~~Capacitor Bank Failure/APFC relay Alarm~~	~~VFC~~	~~24 VDC~~				
7	~~Capacitor Bank Off Status~~	~~VFC~~	~~24 VDC~~				
8	~~Capacitor Bank OverTemp Alarm~~	~~VFC~~	~~24 VDC~~				
9	~~APFC Data~~	~~Soft Link~~	~~Soft Link~~				
10	~~Outgoing Feeder Protection Relay Operation Status~~	24 VDC					
11	~~Outgoing Breaker Local/Remote Status~~	VFC	24 VDC				
12	~~Outgoing Breaker Open Command~~	230 V	VFC				
13	~~Outgoing Breaker Close Command~~	230 V	VFC				
	DB-150 MAIN INCOMING C.B. (ACB)						
1	Incomming Breaker Local/Remote Status	VFC	24 VDC			1	
2	Outgoing Breaker Open Command	230 VAC	VFC				1
3	Incomming Breaker Close Command	230 VAC	VFC				1
4	Incomming Breaker Trip Alarm	Soft Link	Soft Link			DI	
5	Incomming Breaker Close Status	Soft Link	Soft Link			DI	
6	Incomming Breaker Open Status	Soft Link	Soft Link			DI	
7	Incomming Feeder Line Voltage	Soft Link	Soft Link	AI			
8	Incomming Feeder Line Current	Soft Link	Soft Link	AI			
9	~~Incoming Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
	Lift-1 Outgoing C.B. (MCCB)						
1	Breaker Trip Alarm	VFC	24 VDC			1	
2	Breaker Close Status	VFC	24 VDC			1	
3	Breaker Open Status	VFC	24 VDC			1	
	Lift-2 Outgoing C.B. (MCCB)						
1	Breaker Trip Alarm	VFC	24 VDC			1	
2	Breaker Close Status	VFC	24 VDC			1	
3	Breaker Open Status	VFC	24 VDC			1	
	Back up to Lift-3 Outgoing C.B. (MCCB)						
1	Breaker Trip Alarm	VFC	24 VDC			1	
2	Breaker Close Status	VFC	24 VDC			1	
3	Breaker Open Status	VFC	24 VDC			1	
	Back up to Lift-4 Outgoing C.B. (MCCB)						
1	Breaker Trip Alarm	VFC	24 VDC			1	
2	Breaker Close Status	VFC	24 VDC			1	
3	Breaker Open Status	VFC	24 VDC			1	
	Back up to Lift-5 Outgoing C.B. (MCCB)						
1	Breaker Trip Alarm	VFC	24 VDC			1	
2	Breaker Close Status	VFC	24 VDC			1	
3	Breaker Open Status	VFC	24 VDC			1	
	Back to S&T Outgoing C.B. (MCCB)						
1	Breaker Trip Alarm	VFC	24 VDC			1	
2	Breaker Close Status	VFC	24 VDC			1	
3	Breaker Open Status	VFC	24 VDC			1	
	Seepage Pumps Panel, DB-155 Outgoing Breaker (MCCB)						
1	Breaker Trip Alarm	VFC	24 VDC			1	
2	Breaker Close Status	VFC	24 VDC			1	

Sr. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	SIGNAL TYPE			
				AI	AO	DI	DO
3	Breaker Open Status	VFC	24 VDC			1	
	Backup to Seepage Pumps Panel, DB-255 Outgoing CB (MCCB)						
1	Breaker Trip Alarm	VFC	24 VDC			1	
2	Breaker Close Status	VFC	24 VDC			1	
3	Breaker Open Status	VFC	24 VDC			1	
	Escalator Panel, DB-151 Outgoing Breaker (MCCB)						
1	Breaker Trip Alarm	VFC	24 VDC			1	
2	Breaker Close Status	VFC	24 VDC			1	
3	Breaker Open Status	VFC	24 VDC			1	
	Back up to Escalator Panel, DB-251 Outgoing Breaker (MCCB)						
1	Breaker Trip Alarm	VFC	24 VDC			1	
2	Breaker Close Status	VFC	24 VDC			1	
3	Breaker Open Status	VFC	24 VDC			1	
	Battery Charger Outgoing Breaker (MCCB)						
1	Breaker Trip Alarm	VFC	24 VDC			1	
2	Breaker Close Status	VFC	24 VDC			1	
3	Breaker Open Status	VFC	24 VDC			1	
	UPS1 ATS Panel, UDB-180 Outgoing Breaker (MCCB)						
1	Breaker Trip Alarm	VFC	24 VDC			1	
2	Breaker Close Status	VFC	24 VDC			1	
3	Breaker Open Status	VFC	24 VDC			1	
	Back up to UPS-2 ATS Panel, UDB-280 Outgoing Breaker (MCCB)						
1	Breaker Trip Alarm	VFC	24 VDC			1	
2	Breaker Close Status	VFC	24 VDC			1	
3	Breaker Open Status	VFC	24 VDC			1	
	Spare Outgoing Breaker-1 (MCCB)						
1	Breaker Trip Alarm	VFC	24 VDC			1	
2	Breaker Close Status	VFC	24 VDC			1	
3	Breaker Open Status	VFC	24 VDC			1	
	Spare Outgoing Breaker-2 (MCCB)						
1	Breaker Trip Alarm	VFC	24 VDC			1	
2	Breaker Close Status	VFC	24 VDC			1	
3	Breaker Open Status	VFC	24 VDC			1	
	FROM DB-110						
	Backup to Sewage Pumps Panel, DB-211 Outgoing CB (MCCB)						
1	Breaker Trip Alarm	VFC	24 VDC			1	
2	Breaker Close Status	VFC	24 VDC			1	
3	Breaker Open Status	VFC	24 VDC			1	
	FROM UPS ATS 100						
	UPS ATS MAIN INCOMING C.B.						
1	ATS/ PLC Auto/Manual Status	VFC/Soft Link	24 VDC			1	
2	Primary Breaker Trip Alarm	VFC/Soft Link	24 VDC			1	
3	Primary Breaker Close Status	VFC/Soft Link	24 VDC			1	
4	Primary Breaker Open Status	VFC/Soft Link	24 VDC			1	
5	Secondary Breaker Trip Alarm	VFC/Soft Link	24 VDC			1	
6	Secondary Breake Close Status	VFC/Soft Link	24 VDC			1	
7	Secondary Breake Open Status	VFC/Soft Link	24 VDC			1	
8	~~Incoming Feeder Line Voltage~~	~~Soft Link~~	~~Soft Link~~				
9	~~Incoming Feeder Line Current~~	~~Soft Link~~	~~Soft Link~~				
10	~~Incoming Feeder Volt Ampere (VA)~~	~~Soft Link~~	~~Soft Link~~				
11	~~Incoming Feeder Frequency (Hz)~~	~~Soft Link~~	~~Soft Link~~				
12	~~Incoming Feeder Power Factor (PF)~~	~~Soft Link~~	~~Soft Link~~				
13	~~Incoming Feeder Kilo Watt Hour (KWhr)~~	~~Soft Link~~	~~Soft Link~~				
14	~~Incoming Feeder Volt Ampere Reactive (VAR)~~	~~Soft Link~~	~~Soft Link~~				

Sr. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	SIGNAL TYPE			
				AI	AO	DI	DO
15	Dual Supply Status	VFC	24 VDC			1	
16	Main supply off alarm	VFC	24 VDC			1	
17	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
	UPS-1 System						
	UPS-A						
1	UPS01-A Input Voltage	Soft Link	Soft Link	AI			
2	UPS01-A Input Frequency	Soft Link	Soft Link	AI			
3	UPS01-A Input Power Factor	Soft Link	Soft Link			DI	
4	UPS01-A Output Voltage	Soft Link	Soft Link	AI			
5	UPS01-A Output Frequncy	Soft Link	Soft Link	AI			
6	UPS01-A Output Power Factor	Soft Link	Soft Link	AI			
7	UPS01-A Rectifier Off	Soft Link	Soft Link			DI	
8	UPS01-A Rectifier Over Temperature	Soft Link	Soft Link			DI	
9	UPS01-A Rectifier Fail	Soft Link	Soft Link			DI	
10	UPS01-A Inverter Off	Soft Link	Soft Link			DI	
11	UPS01-A Inverter Over Temperature	Soft Link	Soft Link			DI	
12	UPS01-A Inverter Fail	Soft Link	Soft Link			DI	
13	UPS01-A Laod On Bypass	Soft Link	Soft Link			DI	
14	UPS01-A Fan failure/Over temp	Soft Link	Soft Link			DI	
15	UPS01-A Emergency Shutdown	Soft Link	Soft Link			DI	
16	UPS01-A Overload	Soft Link	Soft Link			DI	
	Battery UPS-A						
1	Battery Votage	Soft Link	Soft Link			DI	
2	Battery Current	Soft Link	Soft Link	AI			
3	Battery On Load	Soft Link	Soft Link			DI	
4	Battery Over Temp	Soft Link	Soft Link			DI	
	UPS-B						
1	UPS01-B Input Voltage	Soft Link	Soft Link	AI			
2	UPS01-B Input Frequency	Soft Link	Soft Link			DI	
3	UPS01-B Input Power Factor	Soft Link	Soft Link	AI			
4	UPS01-B Output Voltage	Soft Link	Soft Link	AI			
5	UPS01-B Output Frequncy	Soft Link	Soft Link	AI			
6	UPS01-B Output Power Factor	Soft Link	Soft Link	AI			
7	UPS01-B Rectifier Off	Soft Link	Soft Link			DI	
8	UPS01-B Rectifier Over Temperature	Soft Link	Soft Link			DI	
9	UPS01-B Rectifier Fail	Soft Link	Soft Link			DI	
10	UPS01-B Inverter Off	Soft Link	Soft Link			DI	
11	UPS01-B Inverter Over Temperature	Soft Link	Soft Link			DI	
12	UPS01-B Inverter Fail	Soft Link	Soft Link			DI	
13	UPS01-B Laod On Bypass	Soft Link	Soft Link			DI	
14	UPS01-B Overload	Soft Link	Soft Link			DI	
15	UPS01-B Fam failure/Over temp	Soft Link	Soft Link			DI	
16	UPS01-B Emergency Shutdown	Soft Link	Soft Link			DI	
	Battery UPS-B						
1	Battery Votage	Soft Link	Soft Link			DI	
2	Battery Current	Soft Link	Soft Link	AI			
3	Battery On Load	Soft Link	Soft Link			DI	
4	Battery Over Temp	Soft Link	Soft Link			DI	
	FROM DB151						
	DB-151 MAIN INCOMING C.B.						
1	ATS/ PLC Auto/Manual Status	VFC/Soft Link	24 VDC			1	
2	Primary Breaker Trip Alarm	VFC/Soft Link	24 VDC			1	
3	Primary Breaker Close Status	VFC/Soft Link	24 VDC			1	
4	Primary Breaker Open Status	VFC/Soft Link	24 VDC			1	
5	Secondary Breaker Trip Alarm	VFC/Soft Link	24 VDC			1	
6	Secondary Breake Close Status	VFC/Soft Link	24 VDC			1	
7	Secondary Breake Open Status	VFC/Soft Link	24 VDC			1	
8	~~Incoming Feeder Line Voltage~~	~~Soft Link~~	~~Soft Link~~				
9	~~Incoming Feeder Line Current~~	~~Soft Link~~	~~Soft Link~~				
10	~~Incoming Feeder Volt Ampere (VA)~~	~~Soft Link~~	~~Soft Link~~				
11	~~Incoming Feeder Frequency (Hz)~~	~~Soft Link~~	~~Soft Link~~				
12	~~Incoming Feeder Power Factor (PF)~~	~~Soft Link~~	~~Soft Link~~				
13	~~Incoming Feeder Kilo Watt Hour (KWhr)~~	~~Soft Link~~	~~Soft Link~~				
14	~~Incoming Feeder Volt Ampere Reactive (VAR)~~	~~Soft Link~~	~~Soft Link~~				
15	Dual Supply Status	VFC	24 VDC			1	
16	Main supply off alarm	VFC	24 VDC			1	

Sr. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	SIGNAL TYPE			
				AI	AO	DI	DO
17	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
	Escalator-1 OCB Outgoing Breaker (MCCB)						
1	Breaker Trip Alarm	VFC	24 VDC			1	
2	Breaker Close Status	VFC	24 VDC			1	
3	Breaker Open Status	VFC	24 VDC			1	
4	Energy consumption Kwh	Soft Link	Soft Link	AI			
	Escalator-2 OCB Outgoing Breaker (MCCB)						
1	Breaker Trip Alarm	VFC	24 VDC			1	
2	Breaker Close Status	VFC	24 VDC			1	
3	Breaker Open Status	VFC	24 VDC			1	
4	Energy consumption Kwh	Soft Link	Soft Link	AI			
	Escalator-3 OCB Outgoing Breaker (MCCB)						
1	Breaker Trip Alarm	VFC	24 VDC			1	
2	Breaker Close Status	VFC	24 VDC			1	
3	Breaker Open Status	VFC	24 VDC			1	
4	Energy consumption Kwh	Soft Link	Soft Link	AI			
	Escalator-4 OCB Outgoing Breaker (MCCB)						
1	Breaker Trip Alarm	VFC	24 VDC			1	
2	Breaker Close Status	VFC	24 VDC			1	
3	Breaker Open Status	VFC	24 VDC			1	
4	Energy consumption Kwh	Soft Link	Soft Link	AI			
	Escalator-5 OCB Outgoing Breaker (MCCB)						
1	Breaker Trip Alarm	VFC	24 VDC			1	
2	Breaker Close Status	VFC	24 VDC			1	
3	Breaker Open Status	VFC	24 VDC			1	
4	Energy consumption Kwh	Soft Link	Soft Link	AI			
	Escalator-6 OCB Outgoing Breaker (MCCB)						
1	Breaker Trip Alarm	VFC	24 VDC			1	
2	Breaker Close Status	VFC	24 VDC			1	
3	Breaker Open Status	VFC	24 VDC			1	
4	Energy consumption Kwh	Soft Link	Soft Link	AI			
	Escalator-7 OCB Outgoing Breaker (MCCB)						
1	Breaker Trip Alarm	VFC	24 VDC			1	
2	Breaker Close Status	VFC	24 VDC			1	
3	Breaker Open Status	VFC	24 VDC			1	
4	Energy consumption Kwh	Soft Link	Soft Link	AI			
	Escalator-8 OCB Outgoing Breaker (MCCB)						
1	Breaker Trip Alarm	VFC	24 VDC			1	
2	Breaker Close Status	VFC	24 VDC			1	
3	Breaker Open Status	VFC	24 VDC			1	
4	Energy consumption Kwh	Soft Link	Soft Link	AI			
	Escalator-9 OCB Outgoing Breaker (MCCB)						
1	Breaker Trip Alarm	VFC	24 VDC			1	
2	Breaker Close Status	VFC	24 VDC			1	
3	Breaker Open Status	VFC	24 VDC			1	
4	Energy consumption Kwh	Soft Link	Soft Link	AI			
	Escalator-10 OCB Outgoing Breaker (MCCB)						
1	Breaker Trip Alarm	VFC	24 VDC			1	
2	Breaker Close Status	VFC	24 VDC			1	
3	Breaker Open Status	VFC	24 VDC			1	
4	Energy consumption Kwh	Soft Link	Soft Link	AI			
	Escalator-11 OCB Outgoing Breaker (MCCB)						
1	Breaker Trip Alarm	VFC	24 VDC			1	
2	Breaker Close Status	VFC	24 VDC			1	

Sr. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	SIGNAL TYPE			
				AI	AO	DI	DO
3	Breaker Open Status	VFC	24 VDC			1	
4	Energy consumption Kwh	Soft Link	Soft Link	AI			
	FIELD						
	Escalator STATUS						
1	Escalator Trip Alarm	VFC	24 VDC			5	
2	Escalator Healthy	VFC	24 VDC			5	
	LIFT STATUS						
1	Lift Trip Alarm	VFC	24 VDC			5	
2	Lift Healthy	VFC	24 VDC			5	
	Lift-1 INCOMING ATS						
1	ATS/ PLC Auto/Manual Status	Soft Link	Soft Link			DI	
2	Primary Breaker Trip Alarm	Soft Link	Soft Link			DI	
3	Primary Breaker Close Status	Soft Link	Soft Link			DI	
4	Primary Breaker Open Status	Soft Link	Soft Link			DI	
5	Secondary Breaker Trip Alarm	Soft Link	Soft Link			DI	
6	Secondary Breake Close Status	Soft Link	Soft Link			DI	
7	Secondary Breake Open Status	Soft Link	Soft Link			DI	
8	Dual Supply Status	VFC	24 VDC			1	
9	Main supply off alarm	VFC	24 VDC			1	
10	Energy consumption Kwh	Soft Link	Soft Link	AI			
	Lift-2 INCOMING ATS						
1	ATS/ PLC Auto/Manual Status	Soft Link	Soft Link			DI	
2	Primary Breaker Trip Alarm	Soft Link	Soft Link			DI	
3	Primary Breaker Close Status	Soft Link	Soft Link			DI	
4	Primary Breaker Open Status	Soft Link	Soft Link			DI	
5	Secondary Breaker Trip Alarm	Soft Link	Soft Link			DI	
6	Secondary Breake Close Status	Soft Link	Soft Link			DI	
7	Secondary Breake Open Status	Soft Link	Soft Link			DI	
8	Dual Supply Status	VFC	24 VDC			1	
9	Main supply off alarm	VFC	24 VDC			1	
10	Energy consumption Kwh	Soft Link	Soft Link	AI			
	DB-180 INCOMING C.B.						
1	~~ATS/ PLC Auto/Manual Status~~	Soft Link	Soft Link				
2	Primary Breaker Trip Alarm	VFC	24 VDC			1	
3	Primary Breaker Close Status	VFC	24 VDC			1	
4	Primary Breaker Open Status	VFC	24 VDC			1	
5	Secondary Breaker Trip Alarm	VFC	24 VDC			1	
6	Secondary Breake Close Status	VFC	24 VDC			1	
7	Secondary Breake Open Status	VFC	24 VDC			1	
8	~~Dual Supply Status~~	Soft Link	Soft Link				
9	~~Main supply off alarm~~	Soft Link	Soft Link				
			Hard Signal	4	0	155	30
			Soft Signal	64	0	94	0

Sr. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	SIGNAL TYPE			
				AI	AO	DI	DO
	PL-MDB-200 Incoming Circuit Breaker (ACB)						
1	Incoming Breaker Local/Auto Status	VFC	24 VDC			1	
2	Incoming Breaker Trip Alarm	Soft Link	Soft Link			DI	
3	Incoming Breaker Close Status	Soft Link	Soft Link			DI	
4	Incoming Breaker Open Status	Soft Link	Soft Link			DI	
5	Incoming Feeder Line Voltage	Soft Link	Soft Link	AI			
6	Incoming Feeder Line Current	Soft Link	Soft Link	AI			
7	Incoming Feeder Volt Ampere (VA)	Soft Link	Soft Link	AI			
8	Incoming Feeder Frequency (Hz)	Soft Link	Soft Link	AI			
9	Incoming Feeder Power Factor (PF)	Soft Link	Soft Link	AI			
10	Incoming Feeder Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
11	Incoming Feeder Volt Ampere Reactive (VAR)	Soft Link	Soft Link	AI			
12	Tie Breaker Close Status - ASS1 TO ASS2(ACB-3)	Soft Link	Soft Link			DI	
13	Tie Breaker Open Status - ASS1 TO ASS2(ACB-3)	Soft Link	Soft Link			DI	
14	Bus-coupler Breaker Close Status(ACB-5)	Soft Link	Soft Link			DI	
15	Bus-coupler Breaker Open Status(ACB-5)	Soft Link	Soft Link			DI	
16	Maximum demand	Soft Link	Soft Link	AI			
17	Control Supply Healthy Status	VFC	24 VDC			1	
18	Emergency stop status	VFC	24 VDC			1	
19	~~Incoming Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
20	~~Incoming Breaker Open/CLOSE Command~~						
21	~~Incoming Breaker Close Command~~						
1	Tie Breaker Close Status - ASS2 TO ASS3	VFC	24 VDC			1	
2	Tie Breaker Open Status - ASS2 TO ASS3	VFC	24 VDC			1	
	Pumps/Escalator DB-250 Outgoing C.B.(ACB)						
1	Outgoing Breaker Local/Remote Status	VFC	24 VDC			1	
2	Outgoing Breaker Open Command	230 VAC	VFC				1
2	Outgoing Breaker Close Command	230 VAC	VFC				1
3	Outgoing Breaker Trip Alarm	Soft Link	Soft Link			DI	
4	Outgoing Breaker Close Status	Soft Link	Soft Link			DI	
5	Outgoing Breaker Open Status	Soft Link	Soft Link			DI	
6	Outgoing Feeder Line Current	Soft Link	Soft Link	AI			
7	Energy consumption Kwh	Soft Link	Soft Link	AI			
8	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
9	~~Outgoing Feeder Line Voltage~~	Soft Link	Soft Link				
	Spare Feeder -01(ACB)						
1	Outgoing Breaker Local/Remote Status	VFC	24 VDC			1	
2	Outgoing Breaker Open Command	230 VAC	VFC				1
2	Outgoing Breaker Close Command	230 VAC	VFC				1
3	Outgoing Breaker Trip Alarm	Soft Link	Soft Link			DI	
4	Outgoing Breaker Close Status	Soft Link	Soft Link			DI	
5	Outgoing Breaker Open Status	Soft Link	Soft Link			DI	
6	Outgoing Feeder Line Current	Soft Link	Soft Link	AI			
7	Energy consumption Kwh	Soft Link	Soft Link	AI			
8	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
9	~~Outgoing Feeder Line Voltage~~	Soft Link	Soft Link				
	Spare Feeder-02(ACB)						
1	Outgoing Breaker Local/Remote Status	VFC	24 VDC			1	
2	Outgoing Breaker Open Command	230 VAC	VFC				1
2	Outgoing Breaker Close Command	230 VAC	VFC				1
3	Outgoing Breaker Trip Alarm	Soft Link	Soft Link			DI	
4	Outgoing Breaker Close Status	Soft Link	Soft Link			DI	
5	Outgoing Breaker Open Status	Soft Link	Soft Link			DI	
6	Outgoing Feeder Line Current	Soft Link	Soft Link	AI			
7	Energy consumption Kwh	Soft Link	Soft Link	AI			
8	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
9	~~Outgoing Feeder Line Voltage~~	Soft Link	Soft Link				

Sr. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	SIGNAL TYPE AI	AO	DI	DO
	Spare Feeder-03(MCCB)						
1	Outgoing Breaker Local/Remote Status	VFC	24 VDC			1	
2	Outgoing Breaker Open Command	230 VAC	VFC				1
2	Outgoing Breaker Close Command	230 VAC	VFC				1
3	Outgoing Breaker Trip Alarm	Soft Link	Soft Link			DI	
4	Outgoing Breaker Close Status	Soft Link	Soft Link			DI	
5	Outgoing Breaker Open Status	Soft Link	Soft Link			DI	
6	Outgoing Feeder Line Current	Soft Link	Soft Link	AI			
7	Energy consumption Kwh	Soft Link	Soft Link	AI			
8	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
9	~~Outgoing Feeder Line Voltage~~	Soft Link	Soft Link				
	Spare Feeder-04(ACB)						
1	Outgoing Breaker Local/Remote Status	VFC	24 VDC			1	
2	Outgoing Breaker Open Command	230 VAC	VFC				1
2	Outgoing Breaker Close Command	230 VAC	VFC				1
3	Outgoing Breaker Trip Alarm	Soft Link	Soft Link			DI	
4	Outgoing Breaker Close Status	Soft Link	Soft Link			DI	
5	Outgoing Breaker Open Status	Soft Link	Soft Link			DI	
6	Outgoing Feeder Line Current	Soft Link	Soft Link	AI			
7	Energy consumption Kwh	Soft Link	Soft Link	AI			
8	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
9	~~Outgoing Feeder Line Voltage~~	Soft Link	Soft Link				
	Spare Feeder-05(MCCB)						
1	Outgoing Breaker Local/Remote Status	VFC	24 VDC			1	
2	Outgoing Breaker Open Command	230 VAC	VFC				1
2	Outgoing Breaker Close Command	230 VAC	VFC				1
3	Outgoing Breaker Trip Alarm	Soft Link	Soft Link			DI	
4	Outgoing Breaker Close Status	Soft Link	Soft Link			DI	
5	Outgoing Breaker Open Status	Soft Link	Soft Link			DI	
6	Outgoing Feeder Line Current	Soft Link	Soft Link	AI			
7	Energy consumption Kwh	Soft Link	Soft Link	AI			
8	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
9	~~Outgoing Feeder Line Voltage~~	Soft Link	Soft Link				
	Tunnel Ventilation Fans MCC, DB-240 Outgoing C.B.(ACB)						
1	Outgoing Breaker Local/Remote Status	VFC	24 VDC			1	
2	Outgoing Breaker Open Command	230 VAC	VFC				1
2	Outgoing Breaker Close Command	230 VAC	VFC				1
3	Outgoing Breaker Trip Alarm	Soft Link	Soft Link			DI	
4	Outgoing Breaker Close Status	Soft Link	Soft Link			DI	
5	Outgoing Breaker Open Status	Soft Link	Soft Link			DI	
6	Outgoing Feeder Line Current	Soft Link	Soft Link	AI			
7	Energy consumption Kwh	Soft Link	Soft Link	AI			
8	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
9	~~Outgoing Feeder Line Voltage~~	Soft Link	Soft Link				
	Backup To TVF MCC, DB-140 Outgoing C.B.(ACB)						
1	Outgoing Breaker Local/Remote Status	VFC	24 VDC			1	
2	Outgoing Breaker Open Command	230 VAC	VFC				1
2	Outgoing Breaker Close Command	230 VAC	VFC				1
3	Outgoing Breaker Trip Alarm	Soft Link	Soft Link			DI	
4	Outgoing Breaker Close Status	Soft Link	Soft Link			DI	
5	Outgoing Breaker Open Status	Soft Link	Soft Link			DI	
6	Outgoing Feeder Line Current	Soft Link	Soft Link	AI			
7	Energy consumption Kwh	Soft Link	Soft Link	AI			
8	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
9	~~Outgoing Feeder Line Voltage~~	Soft Link	Soft Link				

Sr. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	SIGNAL TYPE			
				AI	AO	DI	DO
	AHU & TEF MCC, DB-230 Outgoing C.B.(ACB)						
1	Outgoing Breaker Local/Remote Status	VFC	24 VDC			1	
2	Outgoing Breaker Open Command	230 VAC	VFC				1
2	Outgoing Breaker Close Command	230 VAC	VFC				1
3	Outgoing Breaker Trip Alarm	Soft Link	Soft Link			DI	
4	Outgoing Breaker Close Status	Soft Link	Soft Link			DI	
5	Outgoing Breaker Open Status	Soft Link	Soft Link			DI	
6	Outgoing Feeder Line Current	Soft Link	Soft Link	AI			
7	Energy consumption Kwh	Soft Link	Soft Link	AI			
8	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
9	~~Outgoing Feeder Line Voltage~~	Soft Link	Soft Link				
	To DB 170/270 -Chiller Outgoing Circuit Breaker (ACB)						
1	Outgoing Breaker Local/Remote Status	VFC	24 VDC			1	
2	Outgoing Breaker Open Command	230 VAC	VFC				1
3	Outgoing Breaker Close Command	230 VAC	VFC				1
4	Outgoing Breaker Trip Alarm	Soft Link	Soft Link			DI	
5	Outgoing Breaker Close Status	Soft Link	Soft Link			DI	
6	Outgoing Breaker Open Status	Soft Link	Soft Link			DI	
7	Outgoing Feeder Line Current	Soft Link	Soft Link	AI			
8	Energy consumption Kwh	Soft Link	Soft Link	AI			
9	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
10	~~Outgoing Feeder Line Voltage~~	Soft Link	Soft Link				
	Back up to AHU & TEF MCC, DB-130A Outgoing C.B.(ACB)						
1	Outgoing Breaker Local/Remote Status	VFC	24 VDC			1	
2	Outgoing Breaker Open Command	230 VAC	VFC				1
2	Outgoing Breaker Close Command	230 VAC	VFC				1
3	Outgoing Breaker Trip Alarm	Soft Link	Soft Link			DI	
4	Outgoing Breaker Close Status	Soft Link	Soft Link			DI	
5	Outgoing Breaker Open Status	Soft Link	Soft Link			DI	
6	Outgoing Feeder Line Current	Soft Link	Soft Link	AI			
7	Energy consumption Kwh	Soft Link	Soft Link	AI			
8	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
9	~~Outgoing Feeder Line Voltage~~	Soft Link	Soft Link				
	Back up to AHU & TEF MCC, DB-130B Outgoing C.B.(ACB)						
1	Outgoing Breaker Local/Remote Status	VFC	24 VDC			1	
2	Outgoing Breaker Open Command	230 VAC	VFC				1
2	Outgoing Breaker Close Command	230 VAC	VFC				1
3	Outgoing Breaker Trip Alarm	Soft Link	Soft Link			DI	
4	Outgoing Breaker Close Status	Soft Link	Soft Link			DI	
5	Outgoing Breaker Open Status	Soft Link	Soft Link			DI	
6	Outgoing Feeder Line Current	Soft Link	Soft Link	AI			
7	Energy consumption Kwh	Soft Link	Soft Link	AI			
8	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
9	~~Outgoing Feeder Line Voltage~~	Soft Link	Soft Link				
	DG Panel, DB-290 Outgoing Circuit Breaker(ACB)						
1	~~Outgoing Breaker Local/Remote Status~~	~~VFC~~	~~24 VDC~~				
2	~~Outgoing Breaker Open Command~~	~~230 VAC~~	~~VFC~~				
2	~~Outgoing Breaker Close Command~~	~~230 VAC~~	~~VFC~~				
3	Outgoing Breaker Trip Alarm	Soft Link	Soft Link			DI	
4	Outgoing Breaker Close Status	Soft Link	Soft Link			DI	
5	Outgoing Breaker Open Status	Soft Link	Soft Link			DI	
6	Outgoing Feeder Line Current	Soft Link	Soft Link	AI			
7	Energy consumption Kwh	Soft Link	Soft Link	AI			
8	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				

Sr. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	SIGNAL TYPE			
				AI	AO	DI	DO
9	~~Outgoing Feeder Line Voltage~~	Soft Link	Soft Link				
	Lighting DB-220 Outgoing Ckt Breaker(MCCB)						
1	Outgoing Breaker Local/Remote Status	VFC	24 VDC			1	
2	Outgoing Breaker Open Command	230 VAC	VFC				1
2	Outgoing Breaker Close Command	230 VAC	VFC				1
3	Outgoing Breaker Trip Alarm	Soft Link	Soft Link			DI	
4	Outgoing Breaker Close Status	Soft Link	Soft Link			DI	
5	Outgoing Breaker Open Status	Soft Link	Soft Link			DI	
6	Outgoing Feeder Line Current	Soft Link	Soft Link	AI			
7	Energy consumption Kwh	Soft Link	Soft Link	AI			
8	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
9	~~Outgoing Feeder Line Voltage~~	Soft Link	Soft Link				
	Small Power DB-210 Outgoing Ckt Breaker (MCCB)						
1	Outgoing Breaker Local/Remote Status	VFC	24 VDC			1	
2	Outgoing Breaker Open Command	230 VAC	VFC				1
2	Outgoing Breaker Close Command	230 VAC	VFC				1
3	Outgoing Breaker Trip Alarm	Soft Link	Soft Link			DI	
4	Outgoing Breaker Close Status	Soft Link	Soft Link			DI	
5	Outgoing Breaker Open Status	Soft Link	Soft Link			DI	
6	Outgoing Feeder Line Current	Soft Link	Soft Link	AI			
7	Energy consumption Kwh	Soft Link	Soft Link	AI			
8	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
9	~~Outgoing Feeder Line Voltage~~	Soft Link	Soft Link				
	Capacitor Panel, DB-CAP-200 Outgoing C.B.(ACB)						
1	Outgoing Breaker Trip Alarm	VFC	24 VDC			1	
2	Outgoing Breaker Close Status	VFC	24 VDC			1	
3	Outgoing Breaker Open Status	VFC	24 VDC			1	
4	Outgoing Feeder Line Voltage	4-20mA	4-20mA	1			
5	Outgoing Feeder Line Current	4-20mA	4-20mA	1			
6	~~Capacitor Bank Failure/APFC relay Alarm~~	~~VFC~~	~~24 VDC~~				
7	~~Capacitor Bank Off Status~~	~~VFC~~	~~24 VDC~~				
8	~~Capacitor Bank OverTemp Alarm~~	~~VFC~~	~~24 VDC~~				
9	~~APFC Data~~	~~Soft Link~~	~~Soft Link~~				
10	~~Outgoing Feeder Protection Relay Operation Status~~	24 VDC					
11	~~Outgoing Breaker Local/Remote Status~~	VFC	24 VDC				
12	~~Outgoing Breaker Open Command~~	230 V	VFC				
13	~~Outgoing Breaker Close Command~~	230 V	VFC				
	Capacitor Panel, DB-CAP-200 Incomming C.B.(ACB)						
1	Outgoing Breaker Trip Alarm	VFC	24 VDC			1	
2	Outgoing Breaker Close Status	VFC	24 VDC			1	
3	Outgoing Breaker Open Status	VFC	24 VDC			1	
4	Outgoing Feeder Line Voltage	4-20mA	4-20mA	1			
5	Outgoing Feeder Line Current	4-20mA	4-20mA	1			
6	Capacitor Bank Failure/APFC relay Alarm	VFC	24 VDC			1	
7	~~Capacitor Bank Off Status~~	~~VFC~~	~~24 VDC~~				
8	Capacitor Bank OverTemp Alarm	VFC	24 VDC			1	
9	APFC Data	Soft Link	Soft Link	AI			
10	~~Outgoing Feeder Protection Relay Operation Status~~	24 VDC					
11	~~Outgoing Breaker Local/Remote Status~~	VFC	24 VDC				
12	~~Outgoing Breaker Open Command~~	230 V	VFC				
13	~~Outgoing Breaker Close Command~~	230 V	VFC				
	DB-250 MAIN INCOMING C.B.						
1	Incomming Breaker Local/Remote Status	VFC	24 VDC			1	
2	Outgoing Breaker Open Command	230 VAC	VFC				1
3	Incomming Breaker Close Command	230 VAC	VFC				1

Sr. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	SIGNAL TYPE			
				AI	AO	DI	DO
4	Incomming Breaker Trip Alarm	Soft Link	Soft Link			DI	
5	Incomming Breaker Close Status	Soft Link	Soft Link			DI	
6	Incomming Breaker Open Status	Soft Link	Soft Link			DI	
7	Incomming Feeder Line Voltage	Soft Link	Soft Link	AI			
8	Incomming Feeder Line Current	Soft Link	Soft Link	AI			
9	~~Incoming Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
	DB-251 MAIN INCOMING C.B.						
1	Incomming Breaker Local/Remote Status	VFC	24 VDC			1	
2	Outgoing Breaker Open Command	230 VAC	VFC				1
3	Incomming Breaker Close Command	230 VAC	VFC				1
4	Incomming Breaker Trip Alarm	Soft Link	Soft Link			DI	
5	Incomming Breaker Close Status	Soft Link	Soft Link			DI	
6	Incomming Breaker Open Status	Soft Link	Soft Link			DI	
7	Incomming Feeder Line Voltage	Soft Link	Soft Link	AI			
8	Incomming Feeder Line Current	Soft Link	Soft Link	AI			
9	~~Incoming Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
	BACKUP TO Lift-4 Outgoing C.B. (MCCB)						
1	Breaker Trip Alarm	VFC	24 VDC			1	
2	Breaker Close Status	VFC	24 VDC			1	
3	Breaker Open Status	VFC	24 VDC			1	
	BACKUP TO Lift-5 Outgoing C.B. (MCCB)						
1	Breaker Trip Alarm	VFC	24 VDC			1	
2	Breaker Close Status	VFC	24 VDC			1	
3	Breaker Open Status	VFC	24 VDC			1	
	LIFT-1 Outgoing C.B. (MCCB)						
1	Breaker Trip Alarm	VFC	24 VDC			1	
2	Breaker Close Status	VFC	24 VDC			1	
3	Breaker Open Status	VFC	24 VDC			1	
	LIFT-2 Outgoing C.B. (MCCB)						
1	Breaker Trip Alarm	VFC	24 VDC			1	
2	Breaker Close Status	VFC	24 VDC			1	
3	Breaker Open Status	VFC	24 VDC			1	
	LIFT-3 Outgoing C.B. (MCCB)						
1	Breaker Trip Alarm	VFC	24 VDC			1	
2	Breaker Close Status	VFC	24 VDC			1	
3	Breaker Open Status	VFC	24 VDC			1	
	S&T Outgoing C.B. (MCCB)						
1	Breaker Trip Alarm	VFC	24 VDC			1	
2	Breaker Close Status	VFC	24 VDC			1	
3	Breaker Open Status	VFC	24 VDC			1	
	Seepage Pumps Panel, DB-255 Outgoing Breaker (MCCB)						
1	Breaker Trip Alarm	VFC	24 VDC			1	
2	Breaker Close Status	VFC	24 VDC			1	
3	Breaker Open Status	VFC	24 VDC			1	
	Backup to Seepage Pumps Panel, DB-155 Outgoing CB (MCCB)						
1	Breaker Trip Alarm	VFC	24 VDC			1	
2	Breaker Close Status	VFC	24 VDC			1	

Sr. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	SIGNAL TYPE AI	AO	DI	DO
3	Breaker Open Status	VFC	24 VDC			1	
	Escalator Panel, DB-251 Outgoing Breaker (MCCB)						
1	Breaker Trip Alarm	VFC	24 VDC			1	
2	Breaker Close Status	VFC	24 VDC			1	
3	Breaker Open Status	VFC	24 VDC			1	
	Back up to Escalator Panel, DB-151 Outgoing Breaker (MCCB)						
1	Breaker Trip Alarm	VFC	24 VDC			1	
2	Breaker Close Status	VFC	24 VDC			1	
3	Breaker Open Status	VFC	24 VDC			1	
	Battery Charger Outgoing Breaker (MCCB)						
1	Breaker Trip Alarm	VFC	24 VDC			1	
2	Breaker Close Status	VFC	24 VDC			1	
3	Breaker Open Status	VFC	24 VDC			1	
	UPS2 ATS Panel, UDB-280 Outgoing Breaker (MCCB)						
1	Breaker Trip Alarm	VFC	24 VDC			1	
2	Breaker Close Status	VFC	24 VDC			1	
3	Breaker Open Status	VFC	24 VDC			1	
	Back up to UPS-1 ATS Panel, UDB-180 Outgoing Breaker (MCCB)						
1	Breaker Trip Alarm	VFC	24 VDC			1	
2	Breaker Close Status	VFC	24 VDC			1	
3	Breaker Open Status	VFC	24 VDC			1	
	Spare Outgoing Breaker-1 (MCCB)						
1	Breaker Trip Alarm	VFC	24 VDC			1	
2	Breaker Close Status	VFC	24 VDC			1	
3	Breaker Open Status	VFC	24 VDC			1	
	FROM DB-210						
	Sewage Pumps Panel, DB-211 Outgoing Breaker (MCCB)						
1	Breaker Trip Alarm	VFC	24 VDC			1	
2	Breaker Close Status	VFC	24 VDC			1	
3	Breaker Open Status	VFC	24 VDC			1	
	Backup to Pump Room Panel (WTP) Out CB (MCCB)						
1	Breaker Trip Alarm	VFC	24 VDC			1	
2	Breaker Close Status	VFC	24 VDC			1	
3	Breaker Open Status	VFC	24 VDC			1	
	FROM UPS ATS 200						
	UPS ATS MAIN INCOMING C.B.						
1	ATS/ PLC Auto/Manual Status	VFC/Soft Link	24 VDC			1	
2	Primary Breaker Trip Alarm	VFC/Soft Link	24 VDC			1	
3	Primary Breaker Close Status	VFC/Soft Link	24 VDC			1	
4	Primary Breaker Open Status	VFC/Soft Link	24 VDC			1	
5	Secondary Breaker Trip Alarm	VFC/Soft Link	24 VDC			1	
6	Secondary Breake Close Status	VFC/Soft Link	24 VDC			1	
7	Secondary Breake Open Status	VFC/Soft Link	24 VDC			1	
8	~~Incoming Feeder Line Voltage~~	~~Soft Link~~	~~Soft Link~~				
9	~~Incoming Feeder Line Current~~	~~Soft Link~~	~~Soft Link~~				
10	~~Incoming Feeder Volt Ampere (VA)~~	~~Soft Link~~	~~Soft Link~~				
11	~~Incoming Feeder Frequency (Hz)~~	~~Soft Link~~	~~Soft Link~~				

Sr. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	SIGNAL TYPE			
				AI	AO	DI	DO
12	~~Incoming Feeder Power Factor (PF)~~	~~Soft Link~~	~~Soft Link~~				
13	~~Incoming Feeder Kilo Watt Hour (KWhr)~~	~~Soft Link~~	~~Soft Link~~				
14	~~Incoming Feeder Volt Ampere Reactive (VAR)~~	~~Soft Link~~	~~Soft Link~~				
15	Dual Supply Status	VFC	24 VDC			1	
16	Main supply off alarm	VFC	24 VDC			1	
17	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
	UPS-1 System						
	UPS-A						
1	UPS01-A Input Voltage	Soft Link	Soft Link	AI			
2	UPS01-A Input Frequency	Soft Link	Soft Link	AI			
3	UPS01-A Input Power Factor	Soft Link	Soft Link			DI	
4	UPS01-A Output Voltage	Soft Link	Soft Link	AI			
5	UPS01-A Output Frequncy	Soft Link	Soft Link	AI			
6	UPS01-A Output Power Factor	Soft Link	Soft Link	AI			
7	UPS01-A Rectifier Off	Soft Link	Soft Link			DI	
8	UPS01-A Rectifier Over Temperature	Soft Link	Soft Link			DI	
9	UPS01-A Rectifier Fail	Soft Link	Soft Link			DI	
10	UPS01-A Inverter Off	Soft Link	Soft Link			DI	
11	UPS01-A Inverter Over Temperature	Soft Link	Soft Link			DI	
12	UPS01-A Inverter Fail	Soft Link	Soft Link			DI	
13	UPS01-A Laod On Bypass	Soft Link	Soft Link			DI	
14	UPS01-A Fan failure/Over temp	Soft Link	Soft Link			DI	
15	UPS01-A Emergency Shutdown	Soft Link	Soft Link			DI	
16	UPS01-A Overload	Soft Link	Soft Link			DI	
	Battery UPS-A						
1	Battery Votage	Soft Link	Soft Link			DI	
2	Battery Current	Soft Link	Soft Link	AI			
3	Battery On Load	Soft Link	Soft Link			DI	
4	Battery Over Temp	Soft Link	Soft Link			DI	
	UPS-B						
1	UPS01-B Input Voltage	Soft Link	Soft Link	AI			
2	UPS01-B Input Frequency	Soft Link	Soft Link			DI	
3	UPS01-B Input Power Factor	Soft Link	Soft Link	AI			
4	UPS01-B Output Voltage	Soft Link	Soft Link	AI			
5	UPS01-B Output Frequncy	Soft Link	Soft Link	AI			
6	UPS01-B Output Power Factor	Soft Link	Soft Link	AI			
7	UPS01-B Rectifier Off	Soft Link	Soft Link			DI	
8	UPS01-B Rectifier Over Temperature	Soft Link	Soft Link			DI	
9	UPS01-B Rectifier Fail	Soft Link	Soft Link			DI	
10	UPS01-B Inverter Off	Soft Link	Soft Link			DI	
11	UPS01-B Inverter Over Temperature	Soft Link	Soft Link			DI	
12	UPS01-B Inverter Fail	Soft Link	Soft Link			DI	
13	UPS01-B Laod On Bypass	Soft Link	Soft Link			DI	
14	UPS01-B Overload	Soft Link	Soft Link			DI	
15	UPS01-B Fam failure/Over temp	Soft Link	Soft Link			DI	
16	UPS01-B Emergency Shutdown	Soft Link	Soft Link			DI	
	Battery UPS-B						
1	Battery Votage	Soft Link	Soft Link			DI	
2	Battery Current	Soft Link	Soft Link	AI			
3	Battery On Load	Soft Link	Soft Link			DI	
4	Battery Over Temp	Soft Link	Soft Link			DI	
	FROM DB151						
	DB-151 MAIN INCOMING C.B.						
1	ATS/ PLC Auto/Manual Status	VFC/Soft Link	24 VDC			1	
2	Primary Breaker Trip Alarm	VFC/Soft Link	24 VDC			1	
3	Primary Breaker Close Status	VFC/Soft Link	24 VDC			1	
4	Primary Breaker Open Status	VFC/Soft Link	24 VDC			1	
5	Secondary Breaker Trip Alarm	VFC/Soft Link	24 VDC			1	
6	Secondary Breake Close Status	VFC/Soft Link	24 VDC			1	
7	Secondary Breake Open Status	VFC/Soft Link	24 VDC			1	

Sr. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	SIGNAL TYPE			
				AI	AO	DI	DO
8	~~Incoming Feeder Line Voltage~~	~~Soft Link~~	~~Soft Link~~				
9	~~Incoming Feeder Line Current~~	~~Soft Link~~	~~Soft Link~~				
10	~~Incoming Feeder Volt Ampere (VA)~~	~~Soft Link~~	~~Soft Link~~				
11	~~Incoming Feeder Frequency (Hz)~~	~~Soft Link~~	~~Soft Link~~				
12	~~Incoming Feeder Power Factor (PF)~~	~~Soft Link~~	~~Soft Link~~				
13	~~Incoming Feeder Kilo Watt Hour (KWhr)~~	~~Soft Link~~	~~Soft Link~~				
14	~~Incoming Feeder Volt Ampere Reactive (VAR)~~	~~Soft Link~~	~~Soft Link~~				
15	Dual Supply Status	VFC	24 VDC			1	
16	Main supply off alarm	VFC	24 VDC			1	
17	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
	Escalator-5 OCB Outgoing Breaker (MCCB)						
1	Breaker Trip Alarm	VFC	24 VDC			1	
2	Breaker Close Status	VFC	24 VDC			1	
3	Breaker Open Status	VFC	24 VDC			1	
4	Energy consumption Kwh	Soft Link	Soft Link	AI			
	Escalator-6 OCB Outgoing Breaker (MCCB)						
1	Breaker Trip Alarm	VFC	24 VDC			1	
2	Breaker Close Status	VFC	24 VDC			1	
3	Breaker Open Status	VFC	24 VDC			1	
4	Energy consumption Kwh	Soft Link	Soft Link	AI			
	Escalator-7 OCB Outgoing Breaker (MCCB)						
1	Breaker Trip Alarm	VFC	24 VDC			1	
2	Breaker Close Status	VFC	24 VDC			1	
3	Breaker Open Status	VFC	24 VDC			1	
4	Energy consumption Kwh	Soft Link	Soft Link	AI			
	FIELD						
	Escalator STATUS						
1	Escalator Trip Alarm	VFC	24 VDC			5	
2	Escalator Healthy	VFC	24 VDC			5	
	LIFT STATUS						
1	Lift Trip Alarm	VFC	24 VDC			5	
2	Lift Healthy	VFC	24 VDC			5	
	Lift-1 INCOMING ATS						
1	ATS/ PLC Auto/Manual Status	Soft Link	Soft Link			DI	
2	Primary Breaker Trip Alarm	Soft Link	Soft Link			DI	
3	Primary Breaker Close Status	Soft Link	Soft Link			DI	
4	Primary Breaker Open Status	Soft Link	Soft Link			DI	
5	Secondary Breaker Trip Alarm	Soft Link	Soft Link			DI	
6	Secondary Breake Close Status	Soft Link	Soft Link			DI	
7	Secondary Breake Open Status	Soft Link	Soft Link			DI	
8	Dual Supply Status	VFC	24 VDC			1	
9	Main supply off alarm	VFC	24 VDC			1	
10	Energy consumption Kwh	Soft Link	Soft Link	AI			
	Lift-2 INCOMING ATS						
1	ATS/ PLC Auto/Manual Status	Soft Link	Soft Link			DI	
2	Primary Breaker Trip Alarm	Soft Link	Soft Link			DI	
3	Primary Breaker Close Status	Soft Link	Soft Link			DI	
4	Primary Breaker Open Status	Soft Link	Soft Link			DI	
5	Secondary Breaker Trip Alarm	Soft Link	Soft Link			DI	
6	Secondary Breake Close Status	Soft Link	Soft Link			DI	
7	Secondary Breake Open Status	Soft Link	Soft Link			DI	
8	Dual Supply Status	VFC	24 VDC			1	
9	Main supply off alarm	VFC	24 VDC			1	
10	Energy consumption Kwh	Soft Link	Soft Link	AI			

Sr. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	SIGNAL TYPE AI	AO	DI	DO
	DB-280 INCOMING C.B.						
1	~~ATS/ PLC Auto/Manual Status~~	Soft Link	Soft Link				
2	Primary Breaker Trip Alarm	VFC	24 VDC			1	
3	Primary Breaker Close Status	VFC	24 VDC			1	
4	Primary Breaker Open Status	VFC	24 VDC			1	
5	Secondary Breaker Trip Alarm	VFC	24 VDC			1	
6	Secondary Breake Close Status	VFC	24 VDC			1	
7	Secondary Breake Open Status	VFC	24 VDC			1	
8	~~Dual Supply Status~~	Soft Link	Soft Link				
9	~~Main supply off alarm~~	Soft Link	Soft Link				
			Hard Signal	4	0	134	32
			Soft Signal	52	0	93	0

Sr. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	SIGNAL TYPE AI	AO	DI	DO
	FROM DB 155						
	SEEPAGE PANELS JW-MDB-155 Incoming Breaker						
1	ATS/ PLC Auto/Manual Status	VFC	24 VDC			1	
2	Primary Breaker Trip Alarm	Soft Link	Soft Link			DI	
3	Primary Breaker Close Status	Soft Link	Soft Link			DI	
4	Primary Breaker Open Status	Soft Link	Soft Link			DI	
5	Secondary Breaker Trip Alarm	Soft Link	Soft Link			DI	
6	Secondary Breaker Close Status	Soft Link	Soft Link			DI	
7	Secondary Breaker Open Status	Soft Link	Soft Link			DI	
8	DB-155 Mains Incoming Voltage	Soft Link	Soft Link	AI			
9	Dual Supply Status	VFC	24 VDC			1	
10	Main supply off alarm	VFC	24 VDC			1	
11	Energy consumption Kwh	Soft Link	Soft Link	AI			
	Seepage Pump-01						
1	Seepage Pump On/Off Command	230 VAC	VFC				1
2	Seepage Pump Running Feedback	VFC	24 VDC			1	
3	Seepage Pump Local/Remote Status	VFC	24 VDC			1	
4	Seepage Pump Emergency Stop Button Position	VFC	24 VDC			1	
5	Seepage Pump Trip Alarm	VFC	24 VDC			1	
6	Seepage Pump Current	4-20mA	4-20mA	1			
7	Energy consumption Kwh	Soft Link	Soft Link	AI			
	Seepage Pump-02						
1	Seepage Pump On/Off Command	230 VAC	VFC				1
2	Seepage Pump Running Feedback	VFC	24 VDC			1	
3	Seepage Pump Local/Remote Status	VFC	24 VDC			1	
4	Seepage Pump Emergency Stop Button Position	VFC	24 VDC			1	
5	Seepage Pump Trip Alarm	VFC	24 VDC			1	
6	Seepage Pump Current	4-20mA	4-20mA	1			
7	Energy consumption Kwh	Soft Link	Soft Link	AI			
	Seepage Pump-03						
1	Seepage Pump On/Off Command	230 VAC	VFC				1
2	Seepage Pump Running Feedback	VFC	24 VDC			1	
3	Seepage Pump Local/Remote Status	VFC	24 VDC			1	
4	Seepage Pump Emergency Stop Button Position	VFC	24 VDC			1	
5	Seepage Pump Trip Alarm	VFC	24 VDC			1	
6	Seepage Pump Current	4-20mA	4-20mA	1			
7	Energy consumption Kwh	Soft Link	Soft Link	AI			
	Seepage Sump Level						
1	Seepage Sump Low Level Alarm	VFC	24 VDC			1	
2	Seepage Sump High Level Alarm	VFC	24 VDC			1	
3	Seepage Sump High High Level Alarm	VFC	24 VDC			1	
4	Seepage Sump Ultra High Level Alarm	VFC	24 VDC			1	
	Cross Passage/ Mid Tunnel Pump OCB						
1	Outgoing Breaker Trip Alarm	VFC	24 VDC			1	
2	Outgoing Breaker Close Status	VFC	24 VDC			1	
3	Outgoing Breaker Open Status	VFC	24 VDC			1	
	Cross Passage/ Mid Tunnel Pump ICB						
1	Incoming Breaker Trip Alarm	VFC	24 VDC			1	
2	Incoming Breaker Close Status	VFC	24 VDC			1	
3	Incoming Breaker Open Status	VFC	24 VDC			1	
	Cross Passage/ Mid Tunnel Pump-01						
1	Cross Passage Pump On/Off Command	230 VAC	VFC				1
2	Cross Passage Pump Running Feedback	VFC	24 VDC			1	
3	Cross Passage Pump Local/Remote Status	VFC	24 VDC			1	
4	Cross Passage Pump Emergency Stop Button Position	VFC	24 VDC			1	
5	Cross Passage Pump Trip Alarm	VFC	24 VDC			1	
6	Cross Passage Pump Current	4-20mA	4-20mA	1			
7	Energy consumption Kwh	Soft Link	Soft Link	AI			

Sr. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	SIGNAL TYPE AI	AO	DI	DO
	Cross Passage/ Mid Tunnel Pump-02						
1	Cross Passage Pump On/Off Command	230 VAC	VFC				1
2	Cross Passage Pump Running Feedback	VFC	24 VDC			1	
3	Cross Passage Pump Local/Remote Status	VFC	24 VDC			1	
4	Cross Passage Pump Emergency Stop Button Position	VFC	24 VDC			1	
5	Cross Passage Pump Trip Alarm	VFC	24 VDC			1	
6	Cross Passage Pump Current	4-20mA	4-20mA	1			
7	Energy consumption Kwh	Soft Link	Soft Link	AI			
	Cross Passage/ Mid Tunnel Sump Level						
1	Cross Passage/ Mid Tunnel Sump Low Level Status	VFC	24 VDC			1	
2	Cross Passage/ Mid Tunnel Sump High Level Status	VFC	24 VDC			1	
3	Cross Passage/ Mid Tunnel Sump High High Level Status	VFC	24 VDC			1	
	Tunnel Lighting UDB-181						
1	Incoming Breaker Local/Remote Status	VFC	24 VDC			1	
2	Incoming Breaker Trip Alarm	VFC	24 VDC			1	
3	Incoming Breaker Close Status	VFC	24 VDC			1	
4	Incoming Breaker Open Status	VFC	24 VDC			1	
5	Incoming Breaker Open/ CLOSE Command	230 VAC	VFC				1
6	Incoming Feeder Line Voltage	4-20mA	4-20mA	1			
7	Incoming Feeder Line Current	4-20mA	4-20mA	1			
8	Energy consumption Kwh	Soft Link	Soft Link	AI			
	Signage Lighting UDB-182						
1	~~Incoming Breaker Local/Remote Status~~	~~VFC~~	~~24 VDC~~				
2	Incoming Breaker Trip Alarm	VFC	24 VDC			1	
3	Incoming Breaker Close Status	VFC	24 VDC			1	
4	Incoming Breaker Open Status	VFC	24 VDC			1	
5	~~Incoming Breaker Open/ CLOSE Command~~	~~230 VAC~~	~~VFC~~				
6	Incoming Feeder Line Voltage	4-20mA	4-20mA	1			
7	Incoming Feeder Line Current	4-20mA	4-20mA	1			
8	Energy consumption Kwh	Soft Link	Soft Link	AI			
	Public Area Lighting LDB-3 (PUBLIC AREA PF)						
1	Local/Remote Status	VFC	24 VDC			1	
2	On/Off Command - Circuit 1	230 VAC	VFC				1
3	On/Off Status - Circuit 1	VFC	24 VDC			1	
4	On/Off Command - Circuit 2	230 VAC	VFC				1
5	On/Off Status - Circuit 2	VFC	24 VDC			1	
6	On/Off Command - Circuit 3	230 VAC	VFC				1
7	On/Off Status - Circuit 3	VFC	24 VDC			1	
8	Dual Supply Healthy Status	VFC	24 VDC			1	
9	Energy consumption Kwh	Soft Link	Soft Link	AI			
10	~~Local/Remote Status - Circuit 2~~	VFC	24 VDC				
11	~~Local/Remote Status - Circuit 3~~	VFC	24 VDC				
	Public Area Lighting LDB-4 (PUBLIC AREA PF)						
1	Local/Remote Status	VFC	24 VDC			1	
2	On/Off Command - Circuit 1	230 VAC	VFC				1
3	On/Off Status - Circuit 1	VFC	24 VDC			1	
4	On/Off Command - Circuit 2	230 VAC	VFC				1
5	On/Off Status - Circuit 2	VFC	24 VDC			1	
6	On/Off Command - Circuit 3	230 VAC	VFC				1
7	On/Off Status - Circuit 3	VFC	24 VDC			1	
8	Dual Supply Healthy Status	VFC	24 VDC			1	
9	Energy consumption Kwh	Soft Link	Soft Link	AI			
10	~~Local/Remote Status - Circuit 2~~	VFC	24 VDC				
11	~~Local/Remote Status - Circuit 3~~	VFC	24 VDC				
	Public Area Lighting UDB-3 (BOH PF)						
1	Local/Remote Status	VFC	24 VDC			1	
2	On/Off Command - Circuit 1	230 VAC	VFC				1

Sr. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	SIGNAL TYPE AI	AO	DI	DO
3	On/Off Status - Circuit 1	VFC	24 VDC			1	
4	On/Off Command - Circuit 2	230 VAC	VFC				1
5	On/Off Status - Circuit 2	VFC	24 VDC			1	
6	On/Off Command - Circuit 3	230 VAC	VFC				1
7	On/Off Status - Circuit 3	VFC	24 VDC			1	
8	Dual Supply Healthy Status	VFC	24 VDC			1	
9	Energy consumption Kwh	Soft Link	Soft Link	AI			
10	~~Local/Remote Status - Circuit 2~~	VFC	24 VDC				
11	~~Local/Remote Status - Circuit 3~~	VFC	24 VDC				
	Public Area Lighting UDB-1 (PUBLIC AREA PF)						
1	Local/Remote Status	VFC	24 VDC			1	
2	On/Off Command - Circuit 1	230 VAC	VFC				1
3	On/Off Status - Circuit 1	VFC	24 VDC			1	
4	On/Off Command - Circuit 2	230 VAC	VFC				1
5	On/Off Status - Circuit 2	VFC	24 VDC			1	
6	On/Off Command - Circuit 3	230 VAC	VFC				1
7	On/Off Status - Circuit 3	VFC	24 VDC			1	
8	Dual Supply Healthy Status	VFC	24 VDC			1	
9	Energy consumption Kwh	Soft Link	Soft Link	AI			
10	~~Local/Remote Status - Circuit 2~~	VFC	24 VDC				
11	~~Local/Remote Status - Circuit 3~~	VFC	24 VDC				
	Public Area Lighting UDB-2 (PUBLIC AREA PF)						
1	Local/Remote Status	VFC	24 VDC			1	
2	On/Off Command - Circuit 1	230 VAC	VFC				1
3	On/Off Status - Circuit 1	VFC	24 VDC			1	
4	On/Off Command - Circuit 2	230 VAC	VFC				1
5	On/Off Status - Circuit 2	VFC	24 VDC			1	
6	On/Off Command - Circuit 3	230 VAC	VFC				1
7	On/Off Status - Circuit 3	VFC	24 VDC			1	
8	Dual Supply Healthy Status	VFC	24 VDC			1	
9	Energy consumption Kwh	Soft Link	Soft Link	AI			
10	~~Local/Remote Status - Circuit 2~~	VFC	24 VDC				
11	~~Local/Remote Status - Circuit 3~~	VFC	24 VDC				
	MOTORISED OPRATED VALVE-1						
1	MOV open status	VFC	24 VDC			1	
2	MOV Close status	VFC	24 VDC			1	
3	MOV Open/Close command	24 VDC	VFC				1
4	MOV Local/Remote Status	VFC	24 VDC			1	
	MOTORISED OPRATED VALVE-2						
1	MOV open status	VFC	24 VDC			1	
2	MOV Close status	VFC	24 VDC			1	
3	MOV Open/Close command	24 VDC	VFC				1
4	MOV Local/Remote Status	VFC	24 VDC			1	
	Platform Temperature & RH Monitoring						
1	NORTH End Platform RH	4-20mA	4-20mA	1			
2	NORTH End Platform Temperature	4-20mA	4-20mA	1			
	Raw Water in Tunnel Area						
1	Raw Water in Tunnel Area Low Pressure Alarm	VFC	24 VDC			1	

	AI	AO	DI	DO
Hard Signal	10	0	75	21
Soft Signal	14	0	6	0

Sr. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	SIGNAL TYPE			
				AI	AO	DI	DO
	SEEPAGE PANELS DB-255 INCOMING BREAKERS(ATS)						
1	PL-MDB-140 Incoming Breaker	VFC	24 VDC			1	
2	Primary Breaker Trip Alarm	Soft Link	Soft Link			DI	
3	Primary Breaker Close Status	Soft Link	Soft Link			DI	
4	Primary Breaker Open Status	Soft Link	Soft Link			DI	
5	Secondary Breaker Trip Alarm	Soft Link	Soft Link			DI	
6	Secondary Breake Close Status	Soft Link	Soft Link			DI	
7	Secondary Breake Open Status	Soft Link	Soft Link			DI	
8	DB-155 Mains Incoming Voltage	Soft Link	Soft Link	AI			
9	Dual Supply Status	VFC	24 VDC			1	
10	Main supply off alarm	VFC	24 VDC			1	
11	Energy consumption Kwh	Soft Link	Soft Link	AI			
	Seepage Pump-01						
1	Seepage Pump On/Off Command	230 VAC	VFC				1
2	Seepage Pump Running Feedback	VFC	24 VDC			1	
3	Seepage Pump Local/Remote Status	VFC	24 VDC			1	
4	Seepage Pump Emergency Stop Button Position	VFC	24 VDC			1	
5	Seepage Pump Trip Alarm	VFC	24 VDC			1	
6	Seepage Pump Current	4-20mA	4-20mA	1			
7	Energy consumption Kwh	Soft Link	Soft Link	AI			
	Seepage Pump-02						
1	Seepage Pump On/Off Command	230 VAC	VFC				1
2	Seepage Pump Running Feedback	VFC	24 VDC			1	
3	Seepage Pump Local/Remote Status	VFC	24 VDC			1	
4	Seepage Pump Emergency Stop Button Position	VFC	24 VDC			1	
5	Seepage Pump Trip Alarm	VFC	24 VDC			1	
6	Seepage Pump Current	4-20mA	4-20mA	1			
7	Energy consumption Kwh	Soft Link	Soft Link	AI			
	Seepage Pump-03						
1	Seepage Pump On/Off Command	230 VAC	VFC				1
2	Seepage Pump Running Feedback	VFC	24 VDC			1	
3	Seepage Pump Local/Remote Status	VFC	24 VDC			1	
4	Seepage Pump Emergency Stop Button Position	VFC	24 VDC			1	
5	Seepage Pump Trip Alarm	VFC	24 VDC			1	
6	Seepage Pump Current	4-20mA	4-20mA	1			
7	Energy consumption Kwh	Soft Link	Soft Link	AI			
	Seepage Sump Level						
1	Seepage Sump Low Level Alarm	VFC	24 VDC			1	
2	Seepage Sump High Level Alarm	VFC	24 VDC			1	
3	Seepage Sump High High Level Alarm	VFC	24 VDC			1	
4	Seepage Sump Ultra High Level Alarm	VFC	24 VDC			1	
	Cross Passage/ Mid Tunnel Pump OCB						
1	Outgoing Breaker Trip Alarm	VFC	24 VDC			1	
2	Outgoing Breaker Close Status	VFC	24 VDC			1	
3	Outgoing Breaker Open Status	VFC	24 VDC			1	
	Cross Passage/ Mid Tunnel Pump ICB						
1	Incoming Breaker Trip Alarm	VFC	24 VDC			1	
2	Incoming Breaker Close Status	VFC	24 VDC			1	
3	Incoming Breaker Open Status	VFC	24 VDC			1	
	Cross Passage/ Mid Tunnel Pump-01						
1	Cross Passage Pump On/Off Command	230 VAC	VFC				1
2	Cross Passage Pump Running Feedback	VFC	24 VDC			1	
3	Cross Passage Pump Local/Remote Status	VFC	24 VDC			1	
4	Cross Passage Pump Emergency Stop Button Position	VFC	24 VDC			1	
5	Cross Passage Pump Trip Alarm	VFC	24 VDC			1	
6	Cross Passage Pump Current	4-20mA	4-20mA	1			
7	Energy consumption Kwh	Soft Link	Soft Link	AI			

Sr. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	SIGNAL TYPE			
				AI	AO	DI	DO
	Cross Passage/ Mid Tunnel Pump-02						
1	Cross Passage Pump On/Off Command	230 VAC	VFC				1
2	Cross Passage Pump Running Feedback	VFC	24 VDC			1	
3	Cross Passage Pump Local/Remote Status	VFC	24 VDC			1	
4	Cross Passage Pump Emergency Stop Button Position	VFC	24 VDC			1	
5	Cross Passage Pump Trip Alarm	VFC	24 VDC			1	
6	Cross Passage Pump Current	4-20mA	4-20mA	1			
7	Energy consumption Kwh	Soft Link	Soft Link	AI			
	Cross Passage/ Mid Tunnel Sump Level						
1	Cross Passage/ Mid TunnelSump Low Level Status	VFC	24 VDC			1	
2	Cross Passage/ Mid Tunnel Sump High Level Status	VFC	24 VDC			1	
3	Cross Passage/ Mid Tunnel Sump High High Level Status	VFC	24 VDC			1	
	Cross Passage/ Mid Tunnel Sump High High Level Status						
	SEWAGE PANEL DB-211 INCOMING BREAKERS(ATS)						
1	ATS/ PLC Auto/Manual Status	VFC	24 VDC			1	
2	Primary Breaker Trip Alarm	Soft Link	Soft Link			DI	
3	Primary Breaker Close Status	Soft Link	Soft Link			DI	
4	Primary Breaker Open Status	Soft Link	Soft Link			DI	
5	Secondary Breaker Trip Alarm	Soft Link	Soft Link			DI	
6	Secondary Breake Close Status	Soft Link	Soft Link			DI	
7	Secondary Breake Open Status	Soft Link	Soft Link			DI	
8	DB-155 Mains Incoming Voltage	Soft Link	Soft Link	AI			
9	Dual Supply Status	VFC	24 VDC			1	
10	Main supply off alarm	VFC	24 VDC			1	
11	Energy consumption Kwh	Soft Link	Soft Link	AI			
	Sewage Pump-01						
1	Seewage Pump On/Off Command	230 VAC	VFC				1
2	Seewage Pump Running Feedback	VFC	24 VDC			1	
3	Seewage Pump Local/Remote Status	VFC	24 VDC			1	
4	Seepage Pump Emergency Stop Button Position	VFC	24 VDC			1	
5	Seewage Pump Trip Alarm	VFC	24 VDC			1	
6	Seewage Pump Current	4-20mA	4-20mA	1			
7	Energy consumption Kwh	Soft Link	Soft Link	AI			
	Sewage Pump-02						
1	Seewage Pump On/Off Command	230 VAC	VFC				1
2	Seewage Pump Running Feedback	VFC	24 VDC			1	
3	Seewage Pump Local/Remote Status	VFC	24 VDC			1	
4	Seewage Pump Emergency Stop Button Position	VFC	24 VDC			1	
5	Seewage Pump Trip Alarm	VFC	24 VDC			1	
6	Seewage Pump Current	4-20mA	4-20mA	1			
7	Energy consumption Kwh	Soft Link	Soft Link	AI			
	Sewage Sump Level						
1	Sewage Sump Low Level Status	VFC	24 VDC			1	
2	Sewage Sump High Level Status	VFC	24 VDC			1	
	Tunnel Lighting UDB-281						
1	Incoming Breaker Local/Remote Status	VFC	24 VDC			1	
2	Incoming Breaker Trip Alarm	VFC	24 VDC			1	
3	Incoming Breaker Close Status	VFC	24 VDC			1	
4	Incoming Breaker Open Status	VFC	24 VDC			1	
5	Incoming Breaker Open/ CLOSECommand	230 VAC	VFC				1
6	Incoming Feeder Line Voltage	4-20mA	4-20mA	1			
7	Incoming Feeder Line Current	4-20mA	4-20mA	1			
8	Energy consumption Kwh	Soft Link	Soft Link	AI			
	Signage Lighting UDB-282						
1	~~Incoming Breaker Local/Remote Status~~	~~VFC~~	~~24 VDC~~				
2	Incoming Breaker Trip Alarm	VFC	24 VDC			1	
3	Incoming Breaker Close Status	VFC	24 VDC			1	

Sr. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	SIGNAL TYPE AI	AO	DI	DO
4	Incoming Breaker Open Status	VFC	24 VDC			1	
5	~~Incoming Breaker Open/ CLOSE Command~~	~~230 VAC~~	~~VFC~~				
6	Incoming Feeder Line Voltage	4-20mA	4-20mA	1			
7	Incoming Feeder Line Current	4-20mA	4-20mA	1			
8	Energy consumption Kwh	Soft Link	Soft Link	AI			
	Public Area Lighting LDB-1						
1	Local/Remote Status	VFC	24 VDC			1	
2	On/Off Command - Circuit 1	230 VAC	VFC				1
3	On/Off Status - Circuit 1	VFC	24 VDC			1	
4	On/Off Command - Circuit 2	230 VAC	VFC				1
5	On/Off Status - Circuit 2	VFC	24 VDC			1	
6	On/Off Command - Circuit 3	230 VAC	VFC				1
7	On/Off Status - Circuit 3	VFC	24 VDC			1	
8	Dual Supply Healthy Status	VFC	24 VDC			1	
9	Energy consumption Kwh	Soft Link	Soft Link	AI			
10	~~Local/Remote Status - Circuit 2~~	VFC	24 VDC				
11	~~Local/Remote Status - Circuit 3~~	VFC	24 VDC				
	Public Area Lighting LDB-2						
1	Local/Remote Status	VFC	24 VDC			1	
2	On/Off Command - Circuit 1	230 VAC	VFC				1
3	On/Off Status - Circuit 1	VFC	24 VDC			1	
4	On/Off Command - Circuit 2	230 VAC	VFC				1
5	On/Off Status - Circuit 2	VFC	24 VDC			1	
6	On/Off Command - Circuit 3	230 VAC	VFC				1
7	On/Off Status - Circuit 3	VFC	24 VDC			1	
8	Dual Supply Healthy Status	VFC	24 VDC			1	
9	Energy consumption Kwh	Soft Link	Soft Link	AI			
10	~~Local/Remote Status - Circuit 2~~	VFC	24 VDC				
11	~~Local/Remote Status - Circuit 3~~	VFC	24 VDC				
	Public Area Lighting LDB-4 (PUBLIC AREA PF)						
1	Local/Remote Status	VFC	24 VDC			1	
2	On/Off Command - Circuit 1	230 VAC	VFC				1
3	On/Off Status - Circuit 1	VFC	24 VDC			1	
4	On/Off Command - Circuit 2	230 VAC	VFC				1
5	On/Off Status - Circuit 2	VFC	24 VDC			1	
6	On/Off Command - Circuit 3	230 VAC	VFC				1
7	On/Off Status - Circuit 3	VFC	24 VDC			1	
8	Dual Supply Healthy Status	VFC	24 VDC			1	
9	Energy consumption Kwh	Soft Link	Soft Link	AI			
10	~~Local/Remote Status - Circuit 2~~	VFC	24 VDC				
11	~~Local/Remote Status - Circuit 3~~	VFC	24 VDC				
	Public Area Lighting UDB-6 (PUBLIC AREA PF)						
1	Local/Remote Status	VFC	24 VDC			1	
2	On/Off Command - Circuit 1	230 VAC	VFC				1
3	On/Off Status - Circuit 1	VFC	24 VDC			1	
4	On/Off Command - Circuit 2	230 VAC	VFC				1
5	On/Off Status - Circuit 2	VFC	24 VDC			1	
6	On/Off Command - Circuit 3	230 VAC	VFC				1
7	On/Off Status - Circuit 3	VFC	24 VDC			1	
8	Dual Supply Healthy Status	VFC	24 VDC			1	
9	Energy consumption Kwh	Soft Link	Soft Link	AI			
10	~~Local/Remote Status - Circuit 2~~	VFC	24 VDC				

Sr. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	SIGNAL TYPE AI	AO	DI	DO
11	~~Local/Remote Status - Circuit 3~~	VFC	24 VDC				
	Public Area Lighting UDB-7 (PUBLIC AREA PF)						
1	Local/Remote Status	VFC	24 VDC			1	
2	On/Off Command - Circuit 1	230 VAC	VFC				1
3	On/Off Status - Circuit 1	VFC	24 VDC			1	
4	On/Off Command - Circuit 2	230 VAC	VFC				1
5	On/Off Status - Circuit 2	VFC	24 VDC			1	
6	On/Off Command - Circuit 3	230 VAC	VFC				1
7	On/Off Status - Circuit 3	VFC	24 VDC			1	
8	Dual Supply Healthy Status	VFC	24 VDC			1	
9	Energy consumption Kwh	Soft Link	Soft Link	AI			
10	~~Local/Remote Status - Circuit 2~~	VFC	24 VDC				
11	~~Local/Remote Status - Circuit 3~~	VFC	24 VDC				
	Public Area Lighting UDB-8 (BOH PF)						
1	Local/Remote Status	VFC	24 VDC			1	
2	On/Off Command - Circuit 1	230 VAC	VFC				1
3	On/Off Status - Circuit 1	VFC	24 VDC			1	
4	On/Off Command - Circuit 2	230 VAC	VFC				1
5	On/Off Status - Circuit 2	VFC	24 VDC			1	
6	On/Off Command - Circuit 3	230 VAC	VFC				1
7	On/Off Status - Circuit 3	VFC	24 VDC			1	
8	Dual Supply Healthy Status	VFC	24 VDC			1	
9	Energy consumption Kwh	Soft Link	Soft Link	AI			
10	~~Local/Remote Status - Circuit 2~~	VFC	24 VDC				
11	~~Local/Remote Status - Circuit 3~~	VFC	24 VDC				
	MOTORISED OPRATED VALVE-3						
1	MOV open status	VFC	24 VDC			1	
2	MOV Close status	VFC	24 VDC			1	
3	MOV Open/Close command	24 VDC	VFC				1
4	MOV Local/Remote Status	VFC	24 VDC			1	
	MOTORISED OPRATED VALVE-4						
1	MOV open status	VFC	24 VDC			1	
2	MOV Close status	VFC	24 VDC			1	
3	MOV Open/Close command	24 VDC	VFC				1
4	MOV Local/Remote Status	VFC	24 VDC			1	
	Platform Temperature & RH Monitoting						
1	SOUTH End Platform RH	4-20mA	4-20mA	1			
2	SOUTH End Platform Temperature	4-20mA	4-20mA	1			
	Raw Water in Tunnel Area						
1	Raw Water in Tunnel Area Low Pressure Alarm	VFC	24 VDC			1	

Hard Signal	13	0	93	28
Soft Signal	19	0	12	0

S. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	SIGNAL TYPE AI	AO	DI	DO
	DG Set-1						
1	DG Engine Start Feedback	VFC	24 VDC			1	
2	DG common Fault Alarm	VFC	24 VDC			1	
3	DG Battery Voltage	4-20 mA	4-20 mA	1			
4	DG Output Voltage	4-20 mA	4-20 mA	1			
5	DG Output Frequency	4-20 mA	4-20 mA	1			
6	DG Fuel Level	Soft Link	Soft Link	AI			
7	DG Canopy Open Alarm	VFC	24 VDC			1	
8	~~DG On/Off Command~~	~~24 VDC~~	~~24 VDC~~				
9	~~DG Local/Remote Status~~	~~VFC~~	~~24 VDC~~				
	DG Set-2						
1	DG Engine Start Feedback	VFC	24 VDC			1	
2	DG common Fault Alarm	VFC	24 VDC			1	
3	DG Battery Voltage	4-20 mA	4-20 mA	1			
4	DG Output Voltage	4-20 mA	4-20 mA	1			
5	DG Output Frequency	4-20 mA	4-20 mA	1			
6	DG Fuel Level	Soft Link	Soft Link	AI			
7	DG Canopy Open Alarm	VFC	24 VDC			1	
8	~~DG On/Off Command~~	~~24 VDC~~	~~24 VDC~~				
9	~~DG Local/Remote Status~~	~~VFC~~	~~24 VDC~~				
	DG Set-3						
1	DG Engine Start Feedback	VFC	24 VDC			1	
2	DG common Fault Alarm	VFC	24 VDC			1	
3	DG Battery Voltage	4-20 mA	4-20 mA	1			
4	DG Output Voltage	4-20 mA	4-20 mA	1			
5	DG Output Frequency	4-20 mA	4-20 mA	1			
6	DG Fuel Level	Soft Link	Soft Link	AI			
7	DG Canopy Open Alarm	VFC	24 VDC			1	
8	~~DG On/Off Command~~	~~24 VDC~~	~~24 VDC~~				
9	~~DG Local/Remote Status~~	~~VFC~~	~~24 VDC~~				
	DG Panel, DB-290 Incoming Circuit Breaker (DG-01)						
1	Incoming Breaker Trip Alarm	Soft Link	Soft Link			DI	
2	Incoming Breaker Close Status	Soft Link	Soft Link			DI	
3	Incoming Breaker Open Status	Soft Link	Soft Link			DI	
4	Incoming Feeder Line Voltage	Soft Link	Soft Link	AI			
5	Incoming Feeder Line Current	Soft Link	Soft Link	AI			
6	Incoming Feeder Volt Ampere (VA)	Soft Link	Soft Link	AI			
7	Incoming Feeder Frequency (Hz)	Soft Link	Soft Link	AI			
8	Incoming Feeder Power Factor (PF)	Soft Link	Soft Link	AI			
9	Incoming Feeder Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
10	Incoming Feeder Volt Ampere Reactive (VAR)	Soft Link	Soft Link	AI			
11	~~Incoming Breaker Local/Remote Status~~	~~VFC~~	~~24 VDC~~				
12	~~Incoming Breaker Open / Close Command~~	~~230VAC~~	~~230VAC~~				
13	~~Incoming Breaker Close Command~~	~~230VAC~~	~~230VAC~~				
14	~~Incoming Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
	DG Panel, DB-290 Incoming Circuit Breaker (DG-02)						
1	Incoming Breaker Trip Alarm	Soft Link	Soft Link			DI	
2	Incoming Breaker Close Status	Soft Link	Soft Link			DI	
3	Incoming Breaker Open Status	Soft Link	Soft Link			DI	
4	Incoming Feeder Line Voltage	Soft Link	Soft Link	AI			
5	Incoming Feeder Line Current	Soft Link	Soft Link	AI			
6	Incoming Feeder Volt Ampere (VA)	Soft Link	Soft Link	AI			
7	Incoming Feeder Frequency (Hz)	Soft Link	Soft Link	AI			
8	Incoming Feeder Power Factor (PF)	Soft Link	Soft Link	AI			
9	Incoming Feeder Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
10	Incoming Feeder Volt Ampere Reactive (VAR)	Soft Link	Soft Link	AI			
11	~~Incoming Breaker Local/Remote Status~~	~~VFC~~	~~24 VDC~~				
12	~~Incoming Breaker Open / Close Command~~	~~230VAC~~	~~230VAC~~				
13	~~Incoming Breaker Close Command~~	~~230VAC~~	~~230VAC~~				
14	~~Incoming Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
	DG Panel, DB-290 Incoming Circuit Breaker (DG-03)						

S. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	SIGNAL TYPE			
				AI	AO	DI	DO
1	Incoming Breaker Trip Alarm	Soft Link	Soft Link			DI	
2	Incoming Breaker Close Status	Soft Link	Soft Link			DI	
3	Incoming Breaker Open Status	Soft Link	Soft Link			DI	
4	Incoming Feeder Line Voltage	Soft Link	Soft Link	AI			
5	Incoming Feeder Line Current	Soft Link	Soft Link	AI			
6	Incoming Feeder Volt Ampere (VA)	Soft Link	Soft Link	AI			
7	Incoming Feeder Frequency (Hz)	Soft Link	Soft Link	AI			
8	Incoming Feeder Power Factor (PF)	Soft Link	Soft Link	AI			
9	Incoming Feeder Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
10	Incoming Feeder Volt Ampere Reactive (VAR)	Soft Link	Soft Link	AI			
11	~~Incoming Breaker Local/Remote Status~~	~~VFC~~	~~24 VDC~~				
12	~~Incoming Breaker Open / Close Command~~	~~230VAC~~	~~230VAC~~				
13	~~Incoming Breaker Close Command~~	~~230VAC~~	~~230VAC~~				
14	~~Incoming Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
	DB-290 to ASS2 Tie Circuit Breaker						
1	Breaker Trip Alarm	Soft Link	Soft Link			DI	
2	Breaker Close Status	Soft Link	Soft Link			DI	
3	Breaker Open Status	Soft Link	Soft Link			DI	
4	Incoming Feeder Line Voltage	Soft Link	Soft Link	AI			
5	Incoming Feeder Line Current	Soft Link	Soft Link	AI			
6	Incoming Feeder Volt Ampere (VA)	Soft Link	Soft Link	AI			
7	Incoming Feeder Frequency (Hz)	Soft Link	Soft Link	AI			
8	Incoming Feeder Power Factor (PF)	Soft Link	Soft Link	AI			
9	Incoming Feeder Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
10	Incoming Feeder Volt Ampere Reactive (VAR)	Soft Link	Soft Link	AI			
11	DG Synchronising	Soft Link	Soft Link			DI	
11	~~Breaker Local/Remote Status~~	~~VFC~~	~~24 VDC~~				
12	~~Breaker Open / Close Command~~	~~230VAC~~	~~230VAC~~				
13	~~Breaker Close Command~~	~~230VAC~~	~~230VAC~~				
14	~~Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
	Main Fire Pump Panel, DB-260 Outgoing Circuit Breaker						
1	Outgoing Breaker Close Status	VFC	24VDC			1	
2	Outgoing Breaker Open Status	VFC	24VDC			1	
3	Outgoing Breaker Trip Alarm	VFC	24VDC			1	
5	Outgoing Feeder Line Current	4-20 mA	4-20 mA	1			
4	~~Outgoing Feeder Line Voltage~~	~~Soft Link~~	~~Soft Link~~				
6	~~Outgoing Feeder Kilo Watt Hour (KWhr)~~	~~Soft Link~~	~~Soft Link~~				
7	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
8	~~Outgoing Breaker Local/Remote Status~~	~~VFC~~	~~24 VDC~~				
9	~~Outgoing Breaker Open Command~~	~~24 VDC~~	~~24 VDC~~				
10	~~Outgoing Breaker Close Command~~	~~24 VDC~~	~~24 VDC~~				
	Air Scrolled Chiller OCB						
1	Outgoing Breaker Close Status	VFC	24VDC			1	
2	Outgoing Breaker Open Status	VFC	24VDC			1	
3	Outgoing Breaker Trip Alarm	VFC	24VDC			1	
5	Outgoing Feeder Line Current	Soft Link	Soft Link	AI			
4	~~Outgoing Feeder Line Voltage~~	~~Soft Link~~	~~Soft Link~~				
6	~~Outgoing Feeder Kilo Watt Hour (KWhr)~~	~~Soft Link~~	~~Soft Link~~				
7	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
8	~~Outgoing Breaker Local/Remote Status~~	~~VFC~~	~~24 VDC~~				
9	~~Outgoing Breaker Open Command~~	~~24 VDC~~	~~24 VDC~~				
10	~~Outgoing Breaker Close Command~~	~~24 VDC~~	~~24 VDC~~				
	Spare Circuit Breaker-1						
1	Outgoing Breaker Close Status	VFC	24VDC			1	
2	Outgoing Breaker Open Status	VFC	24VDC			1	
3	Outgoing Breaker Trip Alarm	VFC	24VDC			1	
5	Outgoing Feeder Line Current	Soft Link	Soft Link	AI			
4	~~Outgoing Feeder Line Voltage~~	~~Soft Link~~	~~Soft Link~~				
6	~~Outgoing Feeder Kilo Watt Hour (KWhr)~~	~~Soft Link~~	~~Soft Link~~				
7	~~Outgoing Feeder Protection Relay Operation Status~~	~~VFC~~	~~24 VDC~~				
8	~~Outgoing Breaker Local/Remote Status~~	~~VFC~~	~~24 VDC~~				
9	~~Outgoing Breaker Open Command~~	~~24 VDC~~	~~24 VDC~~				
10	~~Outgoing Breaker Close Command~~	~~24 VDC~~	~~24 VDC~~				

S. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	SIGNAL TYPE AI	AO	DI	DO
	DG Aux. Panel, DB-291 Outgoing Circuit Breaker						
1	Outgoing Breaker Trip Alarm	VFC	24 VDC			1	
2	Outgoing Breaker Close Status	VFC	24 VDC			1	
3	Outgoing Breaker Open Status	VFC	24 VDC			1	
	Emergency Tie Breaker Outgoing Circuit Breaker						
1	Outgoing Breaker Trip Alarm	VFC	24 VDC			1	
2	Outgoing Breaker Close Status	VFC	24 VDC			1	
3	Outgoing Breaker Open Status	VFC	24 VDC			1	
	Main Fire Pump Panel. DB-260						
1	ATS/PLC Auto/Manual Status	Soft Link	Soft Link			DI	
2	Primary Breaker Trip status	Soft Link	Soft Link			DI	
3	Primary Breaker Open status	Soft Link	Soft Link			DI	
4	Primary Breaker Close status	Soft Link	Soft Link			DI	
5	Secondary Breaker Trip Status	Soft Link	Soft Link			DI	
6	Secondary Breaker Open Status	Soft Link	Soft Link			DI	
7	Secondary Breaker Close Status	Soft Link	Soft Link			DI	
8	Voltage	Soft Link	Soft Link	AI			
9	Dual Supply Status	VFC	24VDC			1	
10	Main supply off alarm	VFC	24VDC			1	
	MAIN HYDRANT PUMP, P-01						
1	Running Feedback	VFC	24 VDC			1	
2	Emergency Stop Button Position	VFC	24 VDC			1	
3	Trip Alarm	VFC	24 VDC			1	
4	Motor Current	4-20 mA	4-20 mA	1			
~~5~~	~~Low Pressure Alarm~~	~~VFC~~	~~24 VDC~~				
6	Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
7	~~Local/Remote Status~~						
	MAIN HYDRANT PUMP, P-02 (STANDBY)						
1	Running Feedback	VFC	24 VDC			1	
2	Emergency Stop Button Position	VFC	24 VDC			1	
3	Trip Alarm	VFC	24 VDC			1	
4	Motor Current	4-20 mA	4-20 mA	1			
~~5~~	~~Low Pressure Alarm~~	~~VFC~~	~~24 VDC~~				
6	Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
7	~~Local/Remote Status~~						
	Hydrant Jockey Pump						
1	Running Feedback	VFC	24 VDC			1	
2	Emergency Stop Button Position	VFC	24 VDC			1	
3	Trip Alarm	VFC	24 VDC			1	
4	Motor Current	4-20 mA	4-20 mA	1			
~~5~~	~~Low Pressure Alarm~~	~~VFC~~	~~24 VDC~~				
6	Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
7	~~Local/Remote Status~~						
	MAIN Sprinkler PUMP, P-01						
1	Running Feedback	VFC	24 VDC			1	
2	Emergency Stop Button Position	VFC	24 VDC			1	
3	Trip Alarm	VFC	24 VDC			1	
4	Motor Current	4-20 mA	4-20 mA	1			
~~5~~	~~Low Pressure Alarm~~	~~VFC~~	~~24 VDC~~				
6	Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
7	~~Local/Remote Status~~						
	MAIN Sprinkler PUMP, P-02 (STANDBY)						
1	Running Feedback	VFC	24 VDC			1	
2	Emergency Stop Button Position	VFC	24 VDC			1	
3	Trip Alarm	VFC	24 VDC			1	
4	Motor Current	4-20 mA	4-20 mA	1			
~~5~~	~~Low Pressure Alarm~~	~~VFC~~	~~24 VDC~~				
6	Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			

S. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	SIGNAL TYPE			
				AI	AO	DI	DO
7	~~Local/Remote Status~~						
	Sprinkler Jockey Pump						
1	Running Feedback	VFC	24 VDC			1	
2	Emergency Stop Button Position	VFC	24 VDC			1	
3	Trip Alarm	VFC	24 VDC			1	
4	Motor Current	4-20 mA	4-20 mA	1			
~~5~~	~~Low Pressure Alarm~~	~~VFC~~	~~24 VDC~~				
6	Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
7	~~Local/Remote Status~~						
	Spare Pump						
1	Running Feedback	VFC	24 VDC			1	
2	Emergency Stop Button Position	VFC	24 VDC			1	
3	Trip Alarm	VFC	24 VDC			1	
4	Motor Current	4-20 mA	4-20 mA	1			
~~5~~	~~Low Pressure Alarm~~	~~VFC~~	~~24 VDC~~				
6	Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
7	~~Local/Remote Status~~						
	Spare Pump						
1	Running Feedback	VFC	24 VDC			1	
2	Emergency Stop Button Position	VFC	24 VDC			1	
3	Trip Alarm	VFC	24 VDC			1	
4	Motor Current	4-20 mA	4-20 mA	1			
~~5~~	~~Low Pressure Alarm~~	~~VFC~~	~~24 VDC~~				
6	Kilo Watt Hour (KWhr)	Soft Link	Soft Link	AI			
7	~~Local/Remote Status~~						
	Low Pressure alarm						
1	Low Pressure Alarm (Sprinkler pump)	VFC	24 VDC			1	
2	Low Pressure Alarm (Hydrant pump)	VFC	24 VDC			1	
3	Low Pressure Alarm (Jockey pump)	VFC	24 VDC			1	
	Pump room Panel. DB (WTP)						
1	Primary Breaker Trip status	VFC	24 VDC			1	
2	Primary Breaker Open status	VFC	24 VDC			1	
3	Primary Breaker Close status	VFC	24 VDC			1	
4	Secondary Breaker Trip Status	VFC	24 VDC			1	
5	Secondary Breaker Open Status	VFC	24 VDC			1	
6	Secondary Breaker Close Status	VFC	24 VDC			1	
7	Energy consumption Kwh	Soft Link	Soft Link	AI			
8	~~Dual Supply Status~~	~~Soft Link~~	~~Soft Link~~				
9	~~Main supply off alarm~~	~~Soft Link~~	~~Soft Link~~				
10	~~ATS/PLC Auto/Manual Status~~	~~Soft Link~~	~~Soft Link~~				
	Borewell Pump, BWP-01						
1	Pump Local/Remote Status	VFC	24 VDC			1	
2	Pump On/Off Command	230 VAC	VFC				1
3	Pump Running Feedback	VFC	24 VDC			1	
4	Pump Emergency Stop Button Position	VFC	24 VDC			1	
5	Pump Trip Alarm	VFC	24 VDC			1	
6	Pump Current	4-20 mA	4-20 mA	1			
7	~~Pump Kilo Watt Hour (KWhr)~~	Soft Link	Soft Link				
	Borewell Pump, BWP-02						
1	Pump Local/Remote Status	VFC	24 VDC			1	
2	Pump On/Off Command	230 VAC	VFC				1
3	Pump Running Feedback	VFC	24 VDC			1	
4	Pump Emergency Stop Button Position	VFC	24 VDC			1	
5	Pump Trip Alarm	VFC	24 VDC			1	
6	Pump Current	4-20 mA	4-20 mA	1			
7	~~Pump Kilo Watt Hour (KWhr)~~	Soft Link	Soft Link				
	Sump Pump, P-01						
1	Pump Local/Remote Status	VFC	24 VDC			1	

S. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	SIGNAL TYPE AI	AO	DI	DO
2	Pump On/Off Command	230 VAC	VFC				1
3	Pump Running Feedback	VFC	24 VDC			1	
4	Pump Emergency Stop Button Position	VFC	24 VDC			1	
5	Pump Trip Alarm	VFC	24 VDC			1	
6	Pump Current	4-20 mA	4-20 mA	1			
7	~~Pump Kilo Watt Hour (KWhr)~~	Soft Link	Soft Link				
	Sump Pump, P-02						
1	Pump Local/Remote Status	VFC	24 VDC			1	
2	Pump On/Off Command	230 VAC	VFC				1
3	Pump Running Feedback	VFC	24 VDC			1	
4	Pump Emergency Stop Button Position	VFC	24 VDC			1	
5	Pump Trip Alarm	VFC	24 VDC			1	
6	Pump Current	4-20 mA	4-20 mA	1			
7	~~Pump Kilo Watt Hour (KWhr)~~	Soft Link	Soft Link				
	Raw Water Pump, P-01						
1	Pump Local/Remote Status	VFC	24 VDC			1	
2	Pump On/Off Command	230 VAC	VFC				1
3	Pump Running Feedback	VFC	24 VDC			1	
4	Pump Emergency Stop Button Position	VFC	24 VDC			1	
5	Pump Trip Alarm	VFC	24 VDC			1	
6	Pump Current	4-20 mA	4-20 mA	1			
7	~~Pump Kilo Watt Hour (KWhr)~~	Soft Link	Soft Link				
	Raw Water Pump, P-02						
1	Pump Local/Remote Status	VFC	24 VDC			1	
2	Pump On/Off Command	230 VAC	VFC				1
3	Pump Running Feedback	VFC	24 VDC			1	
4	Pump Emergency Stop Button Position	VFC	24 VDC			1	
5	Pump Trip Alarm	VFC	24 VDC			1	
6	Pump Current	4-20 mA	4-20 mA	1			
7	~~Pump Kilo Watt Hour (KWhr)~~	Soft Link	Soft Link				
	Filter Feed Pump , P-01						
1	Pump Local/Remote Status	VFC	24 VDC			1	
2	Pump On/Off Command	230 VAC	VFC				1
3	Pump Running Feedback	VFC	24 VDC			1	
4	Pump Emergency Stop Button Position	VFC	24 VDC			1	
5	Pump Trip Alarm	VFC	24 VDC			1	
6	Pump Current	4-20 mA	4-20 mA	1			
7	~~Pump Kilo Watt Hour (KWhr)~~	Soft Link	Soft Link				
	Filter Feed Pump P-02						
1	Pump Local/Remote Status	VFC	24 VDC			1	
2	Pump On/Off Command	230 VAC	VFC				1
3	Pump Running Feedback	VFC	24 VDC			1	
4	Pump Emergency Stop Button Position	VFC	24 VDC			1	
5	Pump Trip Alarm	VFC	24 VDC			1	
6	Pump Current	4-20 mA	4-20 mA	1			
7	~~Pump Kilo Watt Hour (KWhr)~~	Soft Link	Soft Link				
	Domestic Water Transfer Pump , P-01						
1	Pump Local/Remote Status	VFC	24 VDC			1	
2	Pump On/Off Command	230 VAC	VFC				1
3	Pump Running Feedback	VFC	24 VDC			1	
4	Pump Emergency Stop Button Position	VFC	24 VDC			1	
5	Pump Trip Alarm	VFC	24 VDC			1	
6	Pump Current	4-20 mA	4-20 mA	1			
7	~~Pump Kilo Watt Hour (KWhr)~~	Soft Link	Soft Link				
	Domestic Water Transfer Pump P-02						
1	Pump Local/Remote Status	VFC	24 VDC			1	
2	Pump On/Off Command	230 VAC	VFC				1
3	Pump Running Feedback	VFC	24 VDC			1	
4	Pump Emergency Stop Button Position	VFC	24 VDC			1	
5	Pump Trip Alarm	VFC	24 VDC			1	

S. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE PLC	SIGNAL TYPE AI	AO	DI	DO
6	Pump Current	4-20 mA	4-20 mA	1			
7	~~Pump Kilo Watt Hour (KWhr)~~	Soft Link	Soft Link				
	Makeup Water Pump for Cooling Tower						
1	Pump Local/Remote Status	VFC	24 VDC			1	
2	Pump On/Off Command	230 VAC	VFC				1
3	Pump Running Feedback	VFC	24 VDC			1	
4	Pump Emergency Stop Button Position	VFC	24 VDC			1	
5	Pump Trip Alarm	VFC	24 VDC			1	
6	Pump Current	4-20 mA	4-20 mA	1			
7	~~Pump Kilo Watt Hour (KWhr)~~	Soft Link	Soft Link				
	MOTORISED OPRATED VALVE						
1	MOV open status	VFC	24 VDC			1	
2	MOV Close status	VFC	24 VDC			1	
3	MOV Open/Close command	24 VDC	VFC				1
4	MOV Local/Remote Status	VFC	24 VDC			1	
	Water Softening Plant						
1	Water Parameter	Soft Link	Soft Link	AI			
2	~~Permeate Flow Rate~~	~~4-20 mA~~	~~4-20 mA~~				
3	~~Conductivity~~	~~4-20 mA~~	~~4-20 mA~~				
4	~~Raw water flow rate~~	~~4-20 mA~~	~~4-20 mA~~				
5	~~Operation Status~~	~~VFC~~	~~24 VDC~~				
6	~~Trip Status~~	~~VFC~~	~~24 VDC~~				
	Fire/ Raw/ Treated Water Tanks						
1	Fire Water Tank Low Level Alarm	VFC	24 VDC			1	
2	Fire Water Tank HighLevel	VFC	24 VDC			1	
3	Fire Water Tank very HighLevel	VFC	24 VDC			1	
4	Fire Water Tank Ultra HighLevel	VFC	24 VDC			1	
5	Raw Water Tank Low Level Alarm	VFC	24 VDC			1	
6	Raw Water Tank high Level	VFC	24 VDC			1	
7	Raw Water Tank Very high Level	VFC	24 VDC			1	
8	Raw Water Tank Ultra high Level	VFC	24 VDC			1	
9	Treated Water Tank Low Level Alarm	VFC	24 VDC			1	
10	Treated Water Tank high Level	VFC	24 VDC			1	
11	Treated Water Tank Very high Level	VFC	24 VDC			1	
12	Treated Water Tank Ultra high Level	VFC	24 VDC			1	
			Hard Signal	20	0	109	12
			Soft Signal	41	0	20	0

S. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE			
			AI	AO	DI	DO
	Chilled Water Pump, PL-CHWP-401 Primary					
1	PL-MDB-140 Incoming Breaker	230 VAC				1
2	Flow Status	VFC			1	
3	Running Feedback	VFC			1	
4	Local/Remote Switch Status	VFC			1	
5	Emergency Stop Button Position	VFC			1	
6	Trip	VFC			1	
7	Motor Current	4-20 mA	1			
	Chilled Water Pump, PL-CHWP-402 Primary					
1	On/off Command	230 VAC				1
2	Flow Status	VFC			1	
3	Running Feedback	VFC			1	
4	Local/Remote Switch Status	VFC			1	
5	Emergency Stop Button Position	VFC			1	
6	Trip	VFC			1	
7	Motor Current	4-20 mA	1			
	Chilled Water Pump, PL-CHWP-403 Primary					
1	On/off Command	230 VAC				1
2	Flow Status	VFC			1	
3	Running Feedback	VFC			1	
4	Local/Remote Switch Status	VFC			1	
5	Emergency Stop Button Position	VFC			1	
6	Trip	VFC			1	
7	Motor Current	4-20 mA	1			
	Chilled Water Pump, PL-CHWP-404 Primary					
1	On/off Command	230 VAC				1
2	Flow Status	VFC			1	
3	Running Feedback	VFC			1	
4	Local/Remote Switch Status	VFC			1	
5	Emergency Stop Button Position	VFC			1	
6	Trip	VFC			1	
7	Motor Current	4-20 mA	1			
	Chilled Water Pump, PL-SCHWP-401 Secondary					
1	On/off Command	SOFT LINK				DO
2	Running Feedback				DI	
3	Local/Remote Switch Status				DI	
4	Emergency Stop Button Position				DI	
5	Trip				DI	
6	Motor Current		AI			
7	Flow Status	VFC			1	
	Chilled Water Pump, PL-SCHWP-402 Secondary					
1	On/off Command	SOFT LINK				DO
2	Running Feedback				DI	
3	Local/Remote Switch Status				DI	
4	Emergency Stop Button Position				DI	
5	Trip				DI	
6	Motor Current		AI			
7	Flow Status	VFC			1	
	Chilled Water Pump, PL-SCHWP-403 Secondary					
1	On/off Command	SOFT LINK				DO
2	Running Feedback				DI	
3	Local/Remote Switch Status				DI	
4	Emergency Stop Button Position				DI	
5	Trip				DI	
6	Motor Current		AI			
7	Flow Status	VFC			1	
	Condenser Water Pump, PL-CDWP-401					
1	On/off Command	230 VAC				1
2	Flow Status	VFC			1	
3	Running Feedback	VFC			1	
4	Local/Remote Switch Status	VFC			1	
5	Emergency Stop Button Position	VFC			1	
6	Trip	VFC			1	
7	Motor Current	4-20 mA	1			

S. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE			
			AI	AO	DI	DO
	Condenser Water Pump, PL-CDWP-402					
1	On/off Command	230 VAC				1
2	Flow Status	VFC			1	
3	Running Feedback	VFC			1	
4	Local/Remote Switch Status	VFC			1	
5	Emergency Stop Button Position	VFC			1	
6	Trip	VFC			1	
7	Motor Current	4-20 mA	1			
	Condenser Water Pump, PL-CDWP-403					
1	On/off Command	230 VAC				1
2	Flow Status	VFC			1	
3	Running Feedback	VFC			1	
4	Local/Remote Switch Status	VFC			1	
5	Emergency Stop Button Position	VFC			1	
6	Trip	VFC			1	
7	Motor Current	4-20 mA	1			
	Condenser Water Pump, PL-CDWP-404					
1	On/off Command	230 VAC				1
2	Flow Status	VFC			1	
3	Running Feedback	VFC			1	
4	Local/Remote Switch Status	VFC			1	
5	Emergency Stop Button Position	VFC			1	
6	Trip	VFC			1	
7	Motor Current	4-20 mA	1			
	Cooling Tower, PL-CT-401					
1	Motor # 1 On/off	230 VAC				1
2	Motor # 1 Running Feedback	VFC			1	
3	Motor # 1 Local/Remote Switch Status	VFC			1	
4	Motor # 1 Emergency Stop Button Position	VFC			1	
5	Motor # 1 Trip	VFC			1	
6	Motor # 1 Current	4-20 mA	1			
7	Motor # 1 Vibration	4-20 mA			1	
8	Motor # 2 On/off	230 VAC				1
9	Motor # 2 Running Feedback	VFC			1	
10	Motor # 2 Local/Remote Switch Status	VFC			1	
11	Motor # 2 Emergency Stop Button Position	VFC			1	
12	Motor # 2 Trip	VFC			1	
13	Motor # 2 Current	4-20 mA	1			
14	Motor # 2 Vibration	4-20 mA				1
	Cooling Tower, PL-CT-402					
1	Motor # 1 On/off	230 VAC				1
2	Motor # 1 Running Feedback	VFC			1	
3	Motor # 1 Local/Remote Switch Status	VFC			1	
4	Motor # 1 Emergency Stop Button Position	VFC			1	
5	Motor # 1 Trip	VFC			1	
6	Motor # 1 Current	4-20 mA	1			
7	Motor # 1 Vibration	4-20 mA			1	
8	Motor # 2 On/off	230 VAC				1
9	Motor # 2 Running Feedback	VFC			1	
10	Motor # 2 Local/Remote Switch Status	VFC			1	
11	Motor # 2 Emergency Stop Button Position	VFC			1	
12	Motor # 2 Trip	VFC			1	
13	Motor # 2 Current	4-20 mA	1			
14	Motor # 2 Vibration	4-20 mA			1	
	Cooling Tower, PL-CT-403					
1	Motor # 1 On/off	230 VAC				1
2	Motor # 1 Running Feedback	VFC			1	
3	Motor # 1 Local/Remote Switch Status	VFC			1	
4	Motor # 1 Emergency Stop Button Position	VFC			1	
5	Motor # 1 Trip	VFC			1	
6	Motor # 1 Current	4-20 mA	1			
7	Motor # 1 Vibration	4-20 mA			1	
8	Motor # 2 On/off	230 VAC				1
9	Motor # 2 Running Feedback	VFC			1	
10	Motor # 2 Local/Remote Switch Status	VFC			1	
11	Motor # 2 Emergency Stop Button Position	VFC			1	
12	Motor # 2 Trip	VFC			1	

S. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE			
			AI	AO	DI	DO
13	Motor # 2 Current	4-20 mA	1			
14	Motor # 2 Vibration	4-20 mA			1	
	Temperature Monitoring					
1	Common Chiller header Supply Temperature	4-20 mA	1			
2	Common Chiller header Return Temperature	4-20 mA	1			
3	Cooling Tower Common Outlet Temperature	4-20 mA	1			
4	Cooling Tower Common Inlet Temperature	4-20 mA	1			
	Chiller, PL-CH-401					
1	Chiller On/Off Command	Soft Link				DO
2	Chiller Running Feedback	Soft Link			DI	
3	Chiller Local/Remote Position	Soft Link			DI	
4	Chiller Current Low/High Alarm	Soft Link			DI	
5	Chiller Trip Alarm	Soft Link			DI	
6	Chiller Refrigerant Pressure Low/High Alarm	Soft Link			DI	
7	Chiller Temperature High Alarm	Soft Link			DI	
8	Chiller Water Low Flow Alarm	Soft Link			DI	
9	Condenser Temperature High Alarm	Soft Link			DI	
10	Condenser Water Low Flow Alarm	Soft Link			DI	
	Chiller, PL-CH-402					
1	Chiller On/Off Command	Soft Link				DO
2	Chiller Running Feedback	Soft Link			DI	
3	Chiller Local/Remote Position	Soft Link			DI	
4	Chiller Current Low/High Alarm	Soft Link			DI	
5	Chiller Trip Alarm	Soft Link			DI	
6	Chiller Refrigerant Pressure Low/High Alarm	Soft Link			DI	
7	Chiller Temperature High Alarm	Soft Link			DI	
8	Chiller Water Low Flow Alarm	Soft Link			DI	
9	Condenser Temperature High Alarm	Soft Link			DI	
10	Condenser Water Low Flow Alarm	Soft Link			DI	
	Chiller, PL-CH-403					
1	Chiller On/Off Command	Soft Link				DO
2	Chiller Running Feedback	Soft Link			DI	
3	Chiller Local/Remote Position	Soft Link			DI	
4	Chiller Current Low/High Alarm	Soft Link			DI	
5	Chiller Trip Alarm	Soft Link			DI	
6	Chiller Refrigerant Pressure Low/High Alarm	Soft Link			DI	
7	Chiller Temperature High Alarm	Soft Link			DI	
9	Chiller Water Low Flow Alarm	Soft Link			DI	
8	Condenser Temperature High Alarm	Soft Link			DI	
10	Condenser Water Low Flow Alarm	Soft Link			DI	
	Cooling Tower-01 Level Monitoring					
1	Sump 1 Low Level	VFC			1	
2	Sump 1 High Level	VFC			1	
3	Sump 2 Low Level	VFC			1	
4	Sump 2 High Level	VFC			1	
	Cooling Tower-02 Level Monitoring					
1	Sump 1 Low Level	VFC			1	
2	Sump 1 High Level	VFC			1	
3	Sump 2 Low Level	VFC			1	
4	Sump 2 High Level	VFC			1	
	Cooling Tower-03 Level Monitoring					
1	Sump 1 Low Level	VFC			1	
2	Sump 1 High Level	VFC			1	
3	Sump 2 Low Level	VFC			1	
4	Sump 2 High Level	VFC			1	
	Cooling Tower Bleeder					
1	MOV open status	VFC			1	
2	MOV Close status	VFC			1	
3	MOV Open command	230 VAC				1
4	MOV Close command	230 VAC				1

S. No.	DESCRIPTION	SIGNAL TYPE MCC	SIGNAL TYPE			
			AI	AO	DI	DO
5	MOV Local/Remote Status	VFC			1	
	MOTORISED OPRATED VALVE for CHILLER SYSTEM					
1	MOV open status	VFC			12	
2	MOV Close status	VFC			12	
3	MOV Open command	230 VAC				12
4	MOV Close command	230 VAC				12
5	MOV Local/Remote Status	VFC			12	
	MOTORISED OPRATED VALVE for Air Scrolled CHILLER SYSTEM					
1	MOV open status	VFC			6	
2	MOV Close status	VFC			6	
3	MOV Open/Close command	230 VAC				6
4	MOV Open/Close command	230 VAC				6
5	MOV Local/Remote Status	VFC			6	
	Air Scroll Chilled Water Pump CHWP-1					
1	On/off Command	230 VAC				1
2	Flow Status	VFC			1	
3	Running Feedback	VFC			1	
4	Local/Remote Switch Status	VFC			1	
5	Emergency Stop Button Position	VFC			1	
6	Trip	VFC			1	
7	Motor Current	4-20 mA	1			
	Air Scroll Chilled Water Pump CHWP-2					
1	On/off Command	230 VAC				1
2	Flow Status	VFC			1	
3	Running Feedback	VFC			1	
4	Local/Remote Switch Status	VFC			1	
5	Emergency Stop Button Position	VFC			1	
6	Trip	VFC			1	
7	Motor Current	4-20 mA	1			
	Air Scrolled Chiller, ASCH-01					
1	Sys-1 and 2 On/Off Command	Soft Link				DO
2	Sys-1 Running Feedback	Soft Link			DI	
3	Sys-2 Running Feedback	Soft Link			DI	
4	Sys Local/Remote Position	Soft Link			DI	
5	Chiller Current Low/High Alarm	Soft Link			DI	
6	Sys-1 Trip/ Fault Alarm Alarm	Soft Link			DI	
7	Sys-2 Trip/ Fault Alarm Alarm	Soft Link			DI	
8	Chiller Refrigerant Pressure Low/High Alarm	Soft Link			DI	
9	Chiller Temperature High Alarm	Soft Link			DI	
10	Chiller Water Low Flow Alarm	Soft Link			DI	
11	Condenser Temperature High Alarm	Soft Link			DI	
	Air Scrolled Chiller, ASCH-02					
1	Sys-1 and 2 On/Off Command	Soft Link				DO
2	Sys-1 Running Feedback	Soft Link			DI	
3	Sys-2 Running Feedback	Soft Link			DI	
4	Sys Local/Remote Position	Soft Link			DI	
5	Chiller Current Low/High Alarm	Soft Link			DI	
6	Sys-1 Trip/ Fault Alarm Alarm	Soft Link			DI	
7	Sys-2 Trip/ Fault Alarm Alarm	Soft Link			DI	
8	Chiller Refrigerant Pressure Low/High Alarm	Soft Link			DI	
9	Chiller Temperature High Alarm	Soft Link			DI	
10	Chiller Water Low Flow Alarm	Soft Link			DI	
11	Condenser Temperature High Alarm	Soft Link			DI	
1	Water Flow In line For Chiller1	4-20 ma	1			
2	Water Flow In line For Chiller2	4-20 ma	1			
3	Water Flow In line For Chiller3	4-20 ma	1			
4	Water Flow In line For CT 1	4-20 ma	1			
5	Water Flow In line For CT 2	4-20 ma	1			
6	Water Flow In line For CT 3	4-20 ma	1			
7	Water Flow In line For Makup for CT	4-20 ma	1			
		Hard Signal	27	0	151	55
		Soft Signal	3	0	59	8

S. No.	DESCRIPTION	SIGNAL TYPE FIELD	SIGNAL TYPE PLC	SIGNAL TYPE			
				AI	AO	DI	DO
Interfacing with Fire Alarm System							
1	Fire in Station Zone-1	VFC	24 VDC			1	
2	Fire in Station Zone-2	VFC	24 VDC			1	
3	Fire in Station Zone-3	VFC	24 VDC			1	
4	Fire in Station Zone-4	VFC	24 VDC			1	
5	Fire in Station Zone-5	VFC	24 VDC			1	
6	Fire in Station Zone-6	VFC	24 VDC			1	
7	Fire in Station Zone-7	VFC	24 VDC			1	
8	Fire in Station Zone-8	VFC	24 VDC			1	
9	Fire in Station Zone-9	VFC	24 VDC			1	
10	Fire in Station Zone-10	VFC	24 VDC			1	
11	Fire in Station Zone-11	VFC	24 VDC			1	
12	Fire in Station Zone-12	VFC	24 VDC			1	
13	Fire in Station Zone-13	VFC	24 VDC			1	
14	Fire in Station Zone-14	VFC	24 VDC			1	
15	Fire in Station Zone-15	VFC	24 VDC			1	
	FOR NORTH END						
16	SS1 Local Remote	VFC	24 VDC			1	
17	SS2 Fail/Emerg	VFC	24 VDC			1	
18	SS3 Open /Close	VFC	24 VDC			1	
19	ILPB1 Clear	VFC	24 VDC			1	
20	ILPB2 Confirm	VFC	24 VDC			1	
21	ILPB3 Acknowledge	VFC	24 VDC			1	
22	ILPB4 Concourse	VFC	24 VDC			1	
23	ILPB5 Extract Down	VFC	24 VDC			1	
24	ILPB6 Supply Down	VFC	24 VDC			1	
25	ILPB7 TES Command	VFC	24 VDC			1	
26	ILPB8 EXT Both	VFC	24 VDC			1	
27	ILPB9 Supply Both	VFC	24 VDC			1	
28	ILPB10 Extract UP	VFC	24 VDC			1	
29	ILPB11 Supply UP	VFC	24 VDC			1	
30	L1 Fail	VFC	24 VDC				1
31	L2 Fire	VFC	24 VDC				1
32	L3 Down Left Arrow	VFC	24 VDC				1
33	L4 Down Right Arrow	VFC	24 VDC				1
34	L5 Extract Down Arrow	VFC	24 VDC				1
35	L6 UP Left Arrow	VFC	24 VDC				1
36	L7 UP Right Arrow	VFC	24 VDC				1
37	L8 Extract UP Arrow	VFC	24 VDC				1
	FOR SOUTH END						
38	SS1 Local Remote	VFC	24 VDC			1	
39	SS2 Fail/Emerg	VFC	24 VDC			1	
40	SS3 Open /Close	VFC	24 VDC			1	
41	ILPB1 Clear	VFC	24 VDC			1	
42	ILPB2 Confirm	VFC	24 VDC			1	
43	ILPB3 Acknowledge	VFC	24 VDC			1	
44	ILPB4 Concourse	VFC	24 VDC			1	
45	ILPB5 Extract Down	VFC	24 VDC			1	
46	ILPB6 Supply Down	VFC	24 VDC			1	
47	ILPB7 TES Command	VFC	24 VDC			1	
48	ILPB8 EXT Both	VFC	24 VDC			1	
49	ILPB9 Supply Both	VFC	24 VDC			1	
50	ILPB10 Extract UP	VFC	24 VDC			1	
51	ILPB11 Supply UP	VFC	24 VDC			1	
52	L1 Fail	VFC	24 VDC				1
53	L2 Fire	VFC	24 VDC				1
54	L3 Down Left Arrow	VFC	24 VDC				1

S. No.	DESCRIPTION	SIGNAL TYPE FIELD	SIGNAL TYPE PLC	SIGNAL TYPE			
				AI	AO	DI	DO
55	L4 Down Right Arrow	VFC	24 VDC				1
56	L5 Extract Down Arrow	VFC	24 VDC				1
57	L6 UP Left Arrow	VFC	24 VDC				1
58	L7 UP Right Arrow	VFC	24 VDC				1
59	L8 Extract UP Arrow	VFC	24 VDC				1
			Hard Signal	0	0	43	16

I/O Summry for ECS & TVS System

PLC	BOQ/ Contract								Actual							
	MDB-140 Incoming Brea				Soft Signal				Hard Wire				Soft Signal			
	AI	AO	DI	DO	AI	AO	DI	DO	AI	AO	DI	DO	AI	AO	DI	DO
TVS NORTH PLC	11	0	102	28	1	0	7	0	31	0	172	49	39	0	7	0
TVS SOUTH PLC	10	0	89	25	1	0	7	0	29	0	148	43	52	0	25	1
ECS NORTH PLC	29	4	223	60	3	0	17	0	38	3	205	41	34	0	11	1
ECS SOUTH PLC	29	4	223	60	3	0	17	0	38	3	245	55	33	0	7	0
ECS CHILLER PLC	93	0	253	55	0	0	30	0	59	0	206	23	114	0	353	0
ASS NORTH PLC	39	0	136	17	0	0	0	0	4	0	155	30	64	0	94	0
ASS SOUTH PLC	41	0	139	18	0	0	0	0	4	0	134	32	52	0	93	0
BS NORTH PLC	11	0	61	21	0	0	0	0	10	0	75	21	14	0	6	0
BS SOUTH PLC	11	0	57	18	0	0	0	0	13	0	93	28	19	0	12	0
BS AB PLC	51	0	101	16	0	0	0	0	20	0	109	12	41	0	20	0
VCP	0	0	0	0	0	0	0	0	0	0	43	16	0	0	0	0
Total	325	8	1384	318	8	0	78	0	246	6	1585	350	462	0	628	2
Total Hardwired	2035								2187							
Total Soft					86								1092			
Deviation	152				1006											

PLC	with 20 % spare								No of Card							
	Hard Wire				Soft Signal				Hard Wire				Soft Signal			
	AI	AO	DI	DO	AI	AO	DI	DO	AI	AO	DI	DO	AI	AO	DI	DO
TVS NORTH PLC	38	0	207	59	47	0	9	0	3	0	13	4	57	0	11	0
TVS SOUTH PLC	35	0	178	52	63	0	30	2	3	0	12	4	76	0	36	3
ECS NORTH PLC	46	4	246	50	41	0	14	2	3	1	8	2	50	0	17	3
ECS SOUTH PLC	46	4	294	66	40	0	9	0	3	1	10	3	48	0	11	0
ECS CHILLER PLC	71	0	248	28	137	0	424	0	5	0	8	1	165	0	509	0
ASS NORTH PLC	5	0	186	36	77	0	113	0	1	0	6	2	93	0	136	0
ASS SOUTH PLC	5	0	161	39	63	0	112	0	1	0	6	2	76	0	135	0
BS NORTH PLC	12	0	90	26	17	0	8	0	1	0	3	1	21	0	10	0
BS SOUTH PLC	16	0	112	34	23	0	15	0	1	0	4	2	28	0	18	0
BS AB PLC	24	0	131	15	50	0	24	0	2	0	5	1	60	0	29	0
VCP	0	0	52	20	0	0	0	0	0	0	4	2	0	0	0	0
Total	298	8	1905	425	558	0	758	4	23	2	79	24	674	0	912	6

I/O Summry for CPM

PLC	BOQ/ Contract								Actual							
	Hard Wire				Soft Signal				Hard Wire				Soft Signal			
	AI	AO	DI	DO	AI	AO	DI	DO	AI	AO	DI	DO	AI	AO	DI	DO
CPM	57	24	20	0	29				27	0	151	55	3	0	59	8