CHAPTER 12

ELECTRICAL WORKS

12-1 GENERAL REQUIREMENTS

12-1-1 SCOPE OF WORK

The work included under this section to be furnished and installed by the contractor shall include but not limited to the following:

The complete electrical system for all buildings and pumping stations and treatment units structures included as part of this contract. Including Main Distribution Switchboards, Distribution Panelboards, Lighting Panelboards, motor control centers, switches, metering, wiring devices, and alarm control and communication systems power and communication outlets, junction boxes, wiring cable system incoming lines, feeders, subfeeders, terminal boxes, wiring, connection to equipment furnished and set in place grounding, lighting fixtures, lamps and all other appurtenances required for a complete electrical system in conformance with the intent of this specification and the contract drawings. The contractor shall provide all necessary labor, tools, equipment instrumentation, shop drawings and other materials as may be required to complete the installation testing and placing into operation all electrical system.

12-1-2 STANDARDS

A. The installation shall conform to the applicable rules of international standards and in accordance with best current engineering practices.

The following standards are referred here:

i. Saudi Arabian Standard.

ii. British Standard.

iii. NEMA.

iv. N.E.C.

v. I.E.C.

vi. Or any other internationally accepted practices and codes.

12-1-3 **REQUIREMENTS OF GENERAL SPECIFICATIONS AND MISCELLANEOUS REQUIREMENTS**

The Contractor's attention is directed to the requirements of the General Specifications and Miscellaneous Requirements as herein stated and specifically applicable to Electrical Work as follows:

A) Submission of shop drawings and data, clearly marked to show only items applicable to this specific Contract.

1. Shop drawings required include but not necessarily limited to, the following list:

   - Distribution Panelboards
   - Motor Control Centers
   - Panelboards
   - Conduits, fittings, wires and cables, Wiring Devices and Control devices

2. Early submission shall be made of certain drawings where dimensions of equipment, location of conduit entrances, etc., are important to facilitate construction.

3. Shop Drawings shall include but not be limited to manufacturer's technical literature, single-line diagrams, schematics diagrams and wiring diagrams, equipment layout, panel layout, bills of materials. Other drawings, such as control sequence diagrams, relay diagrams, metering, etc. may also be needed. Each drawing shall be complete, showing all local and remote devices associated with each item. Submissions of shop drawings shall be complete in one package as far as possible including the resubmittal of any drawings previously issued for advance review. Partial submittals may be returned without action. In case of using other than the IEC, NEC and Saudi standards, the Contractor shall submit, along with his proposal, the pertinent extracts from the standards, in English, for the Engineer's review.

4. Bills of Materials shall include a numbered list of all components, with manufacturer's name, catalog number, rating, and other identification. The item number or similar identification, shall appear on all other drawings where the item appears.

5. Time-current characteristic curves for all circuit breakers and fuses.

B) Unless otherwise stated, shop drawings shall be prepared to a scale of 1:50 for all services in the building and 1:25 for equipment areas and similar spaces.

All shop drawings and shall be submitted and approval obtained before any work is put in hand (Five Copies) Drawings shall be re-submitted with the same number until approval is obtained.

As soon as possible after the date of completion of the works, and not more than one month thereafter; the contractor shall prepare and submit to the Engineer, drawings as built of all electrical works as installed Five Copies as well as one reproducible set shall submitted.

C) Instructions for the installation, operation, and maintenance of the equipment, and spare parts list. Standard publications forming a part thereof shall be marked specifically for this Contract. Any non-applicable items shall be crossed out, blanked out, or otherwise deleted. Each drawing shall be complete and correct for the equipment it represents.

Instructions shall be provided for the motor control centers.

D) Nameplates shall be installed on all devices or pieces of equipment for which their use or identification may not be readily apparent, such as, but not limited to, starters, relays, contactors, pushbuttons, indicating lights, and switches.

E) Nameplates shall be made of laminated sheet plastic or of anodized aluminum, appropriate thickness, engraved to provide white letters on a black background, and fastened in place with corrosion-resistant screws. Nameplates shall also be provided on all manufactured assemblies to identify the assembly as well as feeders, circuits, compartments, switches, internal components, etc. nameplates shall be located in a position to be easily readable after completion of the installation of the equipment. Nameplates shall be engraved both in Arabic and in English.

F) Samples of wires and cables, wiring devices, conduit and fittings shall be submitted if requested by the Engineer and shall be in accordance with SASO.

As soon as possible after the award of Contract, the Contractor shall submit all information and data on long delivery items he proposes to use. Early submission for review and early ordering is required to avoid delays in completion of the work.

12-1-4 INTERFERENCE AND ERRONEOUS LOCATIONS

The locations of electrical equipment, devices, outlets, and similar items, as indicated on the drawings, are approximate only. Exact locations shall be as determined or accepted by the Engineer during construction.

The Contractor shall verify in the field all data and normal locations of work, done under other sections of the Specifications, required for the placing of the Electrical work.

In case of interference with other work or erroneous locations with respect to equipment or structures, the Contractor shall furnish all labor and materials necessary to complete the work in an acceptable manner.

12-1-5 **PROTECTION OF ELECTRICAL EQUIPMENT**

Electrical equipment shall be protected from the weather, especially from water dripping or splashing upon it, at all times during shipment, storage, and construction. Equipment shall not be stored out-doors. Where equipment is installed or stored in moist areas, such as unheated buildings, etc., it shall be provided with an acceptable means to prevent moisture damage. This may be a uniformly distributed source of heat to prevent condensation.

12-1-6 **DEFECTIVE OR DAMAGED EQUIPMENT**

Should any equipment or material be subjected to possible damage by water, it shall be dried out thoroughly and put through a special dielectric test as directed, at the expense of the Contractor, or shall be replaced by the Contractor without additional charge.

12-1-7 **APPROVAL AND MARKING OF EQUIPMENT**

Electrical devices and materials shall be listed and/or labeled by the Underwriter's Laboratories, Inc., or equivalent recognized institution wherever standards have been established. Where Underwriter's Laboratories or equivalent recognized institution listing is not available for equipment, the Contractor shall submit certified test reports of an adequately equipped, recognized, independent testing laboratory, approved by the Local Inspecting Authority, indicating that the equipment is in conformance with the requirements. The Contractor shall pay all cost of tests and or inspections necessary for approval of equipment.

All equipment shall have the name or trademark of the manufacturer and the rating in volts and amperes and other pertinent information clearly marked thereon in a location where they can be observed readily after installation.

12-1-8 **ELECTRIC SERVICE**

The Electrical system will operate on 220/380 volt 3-phase, 4-wire, 60 Hz.

This power at the mentioned voltage will be available at the outgoing of the transformer low voltage distribution board supplied and installed by the local power authorities SECO.

The Contractor shall coordinate with SECO for the approved cable type that will be connected to the meter and/or to the distribution board.

The Contractor shall also obtain SECO requirements for locating the meter and shall modify those shown on the Drawings as required, at no extra cost.

12-1-9 **DESCRIPTION OF THE WORK**

All electrical equipment except that located in air conditioned rooms shall be designed for operation in a sand and dust laden atmosphere with 100% humidity and an ambient temperature of 50 ℃. Below grade spaces (wet well and valve chambers) shall be provided with Hazardous Area Class I Div. 1 equipment.

All earth and rock excavation, backfill, concrete, masonry, concrete reinforcement, and construction joints required for electrical work shall conform to the requirements specified under the applicable sections of the specifications.

12-1-10 **DESIGN CRITERIA AND ADEQUACY**

The project is designed based on the following design criteria:

1. Motor rating, as shown on the drawings.
2. Motor direct-on-line starting characteristics, starting current/full load current = 6.5.
3. Indoor ambient temperature 50 ℃.
4. Summer outdoor direct sun exposure skin temperature 70 ℃.
5. Outdoor underground ambient temperature 40 ℃.
6. Soil thermal receptivity 2 ℃ m/W (max.).
7. Soil ambient temperature 26 ℃. (one meter below grade)
8. Altitude 20 x 50 m

The Contractor shall verify the adequacy of the sizes of all equipment under the criteria stated above or any new criteria of the proposed material and shall submit calculations for approval. Any increase of size of any portion of the system shall be performed at no extra cost.

12-2 SUBSTATION TRANSFORMER

12-2-1 General

The Contractor shall supply and install a substation transformer as specified herein and as approved by the Engineer.

12-2-2 General Standards

The transformer shall in general comply with and be tested to IEC Publication 76.

Protection of the transformers against environmental conditions shall be at least equal to that recommended in BS CP 1014 - "Protection of Electrical Power Equipment against climatic conditions".

The transformers shall have an overload capacity at least equal to that defined in IEC Publication 354.

Audible sound level tests shall be carried out in accordance with NEMA Publication TRI-9.04.

Radio Influence Voltage shall be measured as specified in NEMA Publication No. 107.

Transformer oil shall be to BSI148.

High-voltage and low-voltage terminations and cable end boxes shall be in accordance with ESI Standard 35-1, Issue 2, December 1971.

12-2-3 Service Conditions

System Conditions	
Frequency	60Hz
Number of Phases	3
Nominal Voltage	13,800 volts
Maximum Voltage	15,000 volts
Neutral Arrangement	H.V. grounded through a low resistance. L.V. solidly grounded.

12-2-4 Types of Transformer

This Specification covers ground mounted transformers.

All transformers shall be oil immersed, with air cooling ONAN or ONAF.

The voltage ratio shall be 13.8KV/380V as indicated on plans

Tappings shall be provided on the higher voltage winding for a variation of the no-load primary voltage of plus or minus 2.5%.

12-2-5 **Ratings**

Transformer rating shall be as shown on the drawings.

Transformer rated kVA shall be calculated on the following assumptions:

(i) Constant Flux Regulation.
(ii) Continuous Steady load.
(iii) Ambient Temperature of 50 ^{O}C averaged over 24 hours.
(iv) Maximum Gradient of 21 ^{O}C. (Average Winding Temperature minus average oil temperature).
(v) Maximum Winding Hot Spot Temperature of 98 ^{O}C.

After thermal equilibrium has been reached at rated load, the transformer winding hot spot temperature shall not exceed 140 ^{O}C

12-2-6 **Tapping Methods**

All transformers shall be provided with an externally operated self-positioning tapping switch. Provision shall be made for locking of the tapping switch handle, such means incorporating a hold suitable for accommodating a padlock having an 8mm. diameter hasp. Padlocks shall not be provided.

Tapping switches on sealed transformers shall be fitted with a gasketted cover so that the sealing of the transformer under normal conditions is independent of the switch shaft gland.

12-2-7 **Winding Connections**

The transformers 13.8KV/380V shall be connected Delta-Star, in accordance with Vector Group reference BY11 of IEC 76.

The L.V. neutral shall be brought out and fully rated in all cases.

12-2-8 **Losses**

The tenderer shall state the losses guaranteed, subject to the tolerances specified in IEC 76.

The Contractor shall also state the value of magnetising current guaranteed subject to the tolerances specified in IEC 76.

12-2-9 **Impedances**

The guaranteed values of impedance, shall be 5.5% at 75 ^{O}C subject to the tolerances of IEC 76.

12-2-10 **Ability to Withstand Short Circuit**

The transformer shall be designed and constructed to withstand, without damage, the thermal and dynamic effects of external short circuits.

All transformers shall be capable of withstanding, on any tapping, for three seconds without damage an external short circuit between phases.

Transformers without stabilising windings shall be capable of withstanding for three seconds without damage a short circuit between one phase and earth with the neutral of the transformer directly earthed.

Evidence shall be submitted with the tender as to the extent to which the manufacturer has proved or is able to prove either by calculation or test the ability of the specified transformers to withstand on any tapping, without damage under service conditions, the mechanical stresses arising under service conditions, the mechanical stresses arising under short circuit. In accordance with IEC 76 the electromagnetic forces under short circuit shall be as determined from the asymmetrical peak value of the current in the windings, which shall be taken as not greater than 2.55 times the overcurrent r.m.s. value derived from the appropriate conditions specified in the schedules.

12-2-11 **Terminals**

HV and LV terminals shall be brought out through either the tank wall or cover plate.

HV and LV connections to ground mounted transformers are generally made by cable end box, or by direct connection of metalclad equipment.

Transformers shall be with cable end boxes.

Terminals and cable end boxes shall be as follows:

12-2-12 **Cable Box Fixings**

Fixing studs provided on ground mounted transformers for securing H.V. and L.V. cable boxes shall have a minimum projection on the H.V. side of 30 mm and on the L.V. side of 55mm.

All transformers shall be provided with a steel earthing flag suitable for the accommodation of on earthing connection. This flag shall be approximately 63 mm square and of a thickness not less than 6mm, with a central hole having a diameter of 14 mm.

The earthing flag shall be mounted at right angles to the tank side, and in a position approved by the Engineer.

12-2-13 **Tanks**

Transformer tanks shall not leak. The criterion of leakage shall be discolouration by oil of whitewash applied externally to the suspected part, and with an oil temperature of 90 ^{o}C.

All pipes, radiators, fins or corrugations shall be externally welded to the tank wall.

The minimum thickness of steel shall be 3mm. Thicknesses below the minimum value will be considered only in exceptional cases, such as where special protective finishes are used.

If the tank is hermetically sealed or welded, the following requirements shall be met:

(a) The internal pressure shall be atmospheric at an internal temperature of 10 ^{o}C.

(b) The tank shall be designed for an internal pressure of 1.0 bar. It shall be capable of withstanding this pressure indefinitely. It shall also be capable of withstanding an unlimited number of 24 hour cyclic variations of internal pressure from atmospheric to this value. If sealed or welded tanks are offered, the submittal shall include evidence demonstrating compliance with this specification.

12-2-14 **Finish of Tank**

The transformer tank and its accessories shall be adequately protected against corrosion, and the contractor shall include a statement of the method of protection proposed. The quality of protection shall be at least equal to that recommended in BS. CP. 1014. followed by painting, is preferred, but it is recognised that this process can be applied only to the smaller sizes of tank. Larger sizes of tank shall be shot-blasted and then immediately zinc sprayed to on average weight deposited of not less than 550g/m2, followed by a Zinc Chromate based primary paint, and two coats of durable oil and weather resisting point. The final coat of paint shall be dark grey in colour.

The insides of tanks shall be coated with oil-resisting varnish or paint so that the oil cannot come into contact with tank metal at any point.

Alternative methods of corrosion protection shall be subject to the approval of the Engineer.

12-2-15 **Tank Fittings and Attachments**

Transformers shall be provided with the following fittings and attachements:

* Oil Gauge.
* Earthing Terminal.
* Lifting Fittings.
* Rating and Connection Plate.
* Tapping Switch.
* H.V. and L.V. Terminals.
* Tank filling and draining Valves.
* Thermometer Pocket.
* Lifting Fittings.
* Jacking Lugs.
* Protecting Irons.

Oil level gauges shall be of prismatic type, for clear oil level indication. They shall be made of glass and shall be replaceable.

Lifting fittings shall be provided on all transformers. They shall be so disposed as to allow the transformer to be lifted from a single hook.

Thermometer pockets shall be fitted on the transformer. The thermometer shall not foul other fittings, and shall not obscure the oil gauge or tapping switch. The submittal shall include a drawing of the proposed thermometer pocket.

12-2-16 **Rating and Connection Plate**

Each transformer shall be provided with a rating plate of weatherproof material fitted as specified hereinafter showing the following items. the entries on the rating plate shall be indelibly marked:

(a) Kind of Transformer.
(b) Specification to which manufactured IEC 76.
(c) Manufacturer's name.
(d) Manufacturer's serial number.
(e) Year of manufacture.
(f) Number of phases.
(g) Rated power. - KVA
(h) Rated frequency - Hz
(i) Rated voltages. - KV
(j) Rated currents. - Amps.
(k) Vector group symbol.
(l) Impedance voltage at rated current - percent (Measured value).
(m) Type of cooling. ONAN
(n) Ambient temperature at which ratings apply. ^{o}C.

(o) Top oil temperature rise at rated load. ^{o}C.
(p) Total pass. - Kg.
(q) Volume of oil. Litres.
(r) Mass of core and windings. Kgs.

All information on the rating plate shall be written in English.

12-2-17 **Noise**

The average surface noise level of the transformers shall not exceed 58 db.

The measurement shall be carried out in accordance with NEMA Publication No. TR. 1 9.04.

12-2-18 **Insulation**

Terminations shall be adequate for the winding tests, and shall flashover externally before puncture or internal failure.

The following insulation values shall apply.

Winding	H.V.	L.V.		
Impulse Voltage	125 Kv	Power Frequence	38kV	2.5 kV Test Voltage

The above voltages shall be as defined in IEC Publication 76.

12-2-19 **Routine Tests**

Routine tests shall be carried out on all transformers, and shall be free of charge. They shall be, at the client's option, witnessed by the Engineer.

The tests shall be carried out in accordance with IEC 76 where this is applicable.

The following routing tests shall be carried out:

(a) Measurement of winding resistance.
(b) Voltage ratio measurement and check of polarity or vector-group symbol, - at all top positions.
(c) Measurement of impedance voltages.
(d) Measurement of load loss.
(e) Measurement of no-load loss and current.
(f) Induced overvoltage withstand test - 22kV for 60 seconds on the H.V. Windings.
(g) Separate source voltage withstand tests on H.V. and L.V. windings.

Winding:	H.V.	L.V.
Voltage:	38kV	2.5kV

(h) Leakage Test. The criterion of leakage shall be discolouration by oil of whitesash applied externally to suspected parts at an oil temperature of 90 ^{o}C.

The results of these tests shall be recorded on a Routing Test Certificate, and two copies of this shall be sent to the Engineer immediately after the tests. The transformers shall be not dispatched until the Engineers written approval of the relevant Routing Test Certificate has been given.

Routine Test Certificates shall include, in addition to the test results,

(a) the Contractor order number.
(b) the Manufacturer's serial number.

12-2-20 **Drawings**

The following drawings shall be provided by the Contractor for the transformer(s):

(a) Outline of transformer showing disposition of fittings and attachements.
(b) Details of H.V. and L.V. terminals.
(c) Mounting arrangements.

12-2-21 **Delivery**

The Submittal shall give a guaranteed delivery time from the date of receipt of an official order to despatch of materials from the works.

12-2-22 **Guarantee**

The Contractor shall guarantee the transformer(s) against all defects arising out of faulty design or workmanship, or of defective material for a period of one year from date of commissioning. The client's certificates for date of commissioning shall be accepted.

12-3 MEDIUM TENSION SWITCHGEAR (24 KV)

12-3-1 GENERAL CONDITIONS

The following specifications apply to modular air insulated indoor switchgear comprising factory built, metal-enclosed compartmented switchgear assemblies.

The equipment to be supplied shall consist of aligned cubicles satisfying the following criteria:

open-ended design,
easy to install,
safe and easy to operate,
compact design,
low maintenance.

The supplier must be able to prove that he possesses extensive experience in the field of MV switchgear, that he has already supplied equipment of the same type and same make and that this equipment has been in operation for at least three years.

Approved suppliers: Merlin Gerin, (France), Siemens (Germany) Holec (Netherland) ABB (Germany)

12-3-2 STANDARDS

The switchgear shall comply with the latest issues of the following IEC recommendations:

IEC 298 AC metal-enclosed switchgear and control gear for rated voltages above 1 kV and up to and including 54 kV,

IEC 265	High-voltage switches,
IEC 129	AC disconnectors and earthing switches,
IEC 694	Common dauses for high-voltages switchgear and control gear,
IEC 420	High-voltage AC switch-fuse combinations.
IEC 56	High-voltage AC circuit breakers,
IEC 282-1	High-voltage fuses,
IEC 185	Current transformers,
IEC 186	Voltage transformers,
IEC 801	Electromagnetic compatibility for industrial process measurement and control equipment.
IEC 255	Relays

12-3-3 **RATED VOLTAGE AND SHORT-TIME WITHSTAND CURRENT**

The switchgear shall be suitable for three-phase systems operating at 13.8 kV, and 60 Hz, voltage level being determined by SASO.

The rated voltage shall be at least 24 kV.

The short-time withstand current shall be 20 kA-1 s.

All switchgear shall be capable of withstanding the above conditions without provoking damage, in accordance with paragraphs 4.5, 4.6 and 4.7 of IEC 694 and paragraph 4.5 of IEC 298 recommendations.

12-3-4 **INSULATION LEVEL**

The insulation level of the switchgear shall comply with IEC recommendations and the values indicated in the following table:

General Specification for Modular Metal-enclosed Switchgear (24 kV)

Insulation level

Rated Voltage			24
60 Hz/1 min.	insulation	50	
(kV rms)	isolation		60
1.2/50 ,us insulation	insulation	125	
(kV peak) isolation	isolation	145	

12-3-5 **LOAD BREAK SWITCH**

A. **General**

Load Break switch shall be incorporated with HRC fuses load break switches shall interrupt currents up to their rated current as well as they shall handle short circuit currents.

All load break switches shall be motorized and withdrawable.

B. **Operation**

Load Break switches shall operate on the vertical break principle with enclosed hard gas arcing chambers. During the opening cycle of the movable contact arm, a pilot electrical maintains current flow through the isolating gap. The switching arc is drawn inside a hard plastic arcing tube, forming a cylinder in which the movable contact acts as piston. Gas released from the cylinder in which the movable contact acts as piston.

Gas released from the cylinder wall during arcing, and forced into the break by pumping action of the piston deeioni zes the swithching gap at natural zero.

At the end of the movable contact arm travel, the pilot electrode shall open and establish the visible isolating gap the safety codes require. During closing, the pre-strike arc is carried momentarily by arcing horns on the top of the main movable contacts.

C. **Operating Mechanism**

Operating mechanism shall consist of stored energy opening and closing mechanism and electric motor operation.

Shunt trip coils and mechanical releases shall be provided for fuse striker Pins.

Earthing switches shall be added on line and load side. All accessory auxiliary contacts shall be provided for remote position indication.

D. **Technical Description - (Specific Data)**

Rated Voltage		KV		24
Power Frequency withstand Voltage	KV		36	
Lighting Impulse withstand Voltage	KV		95	
Frequency		Hz		60
Rated Short Circuit Making Current	KA		53	
Rated Short Circuit Breaking Current		KA		21
Standard Color of Outer Surfaces		RAL		7032
Ambient Temperature (Basis of Rating)		℃		55
Maximum Ambient Temperature		℃		55
Minimum Ambient Temperature		℃		05
Degree of Protection According to IEC 529 (Door Closed)		IP		40

E. **High Voltage HRC Fuses**

High voltage HRC cartridyes shall be highly current limiting silver alloy fuses for short circuit protection. Typical arcing times shall be less than 10 ms, max., let through currents are between 0.12 and 7 KA.

The main fusible links shall be made from precisely calibrated silver alloy stampings. These are wound around ceramic cylinders which are embedded in quartz sand for arc extinction.

A secondary spring loaded fusible link retains the striker pin indicator inside the outer protection sleeve. The entire element is entirely sealed with silver plated brass caps which also serve as contact elements for the fuse clips.

Suitable fuse bases and carriers shall be available for attachments to load break switches.

12-3-6 EARTHING FACILITIES

A. Earthing of Metal Parts

All metal parts of the cubicle shall be interconnected and connected to a copper earth bus running along the switchboard.

The cross section of this copper bus shall be signed to withstand the rated short circuit current of the switchgear for three seconds, in compliance with the IEC testing Procedure .

B. Earthing of Circuit and Busbar

1) Circuit Earthing

Provision shall be made for earthing of cables preferably by means of an integral earthing swicthing with of the quick make type, able to earth the cables even when the circuit breaker is in disconnected position.

The earthing switch shall be located in the cable compartment and shall be operated form the front of any cubicle. This earthing device shall be able to close against the rated short circuit current and shall have only two positions, open or closed. Padlocking facilities shall be fitted to enable the earthing switch to be locked in both positions. The position of the integral earthing switch shall be clearly visible from the front of the switchboard. Mechanical interlocks shall be provided to avoid any maloperation such as:

- Closing of earthing switch if the breaker is in service position,
- Inserting of breaker if the earthing switch is in closed position. Integral earthing o f the breaker transfer type is not acceptable.

2) Busbar earthing

Facilities for busbar earthing using integral earthing switches located on each section of the busbar or earthing truck shall be provided. Where integral earthing switches are used, these shall have the same features as the circuit earthing switches.

Alternatively, a truck with an earthing switch having the same features as above can be offered, should this be the case, one busbar earthing truck shall be provided for each sub-station. To prevent any mishandling during earthing operations, interlocking facilities shall be provided to avoid:

- insertion of the earthing truck when earthing switch is in closed position,
- removal of the earthing truck when earthing switch is in closed Position.

In addition, keylocking or padlocking facilities shall be provided for both the truck and the earthing switch in all positions .

Should an earthing truck be provided, then it can also earth the circuit once the connecting conductors shave been set up in the relevant position. A set of three neon lamps located on the front of the truck shall indicate whether the cables are energized or not.

12-3-7 ISOLATING FACILITIES

The circuit breaker shall be withdrawable from the fixed part of the cubicle and shall ensure isolation between busbars and circuits when disconnected. Vertical withdrawable type will not be considered.

A set of two safety metallic shutters shall be positively driven by the circuit breaker during withdrawal to prevent any access to the live fixed contacts. These shutters shall cover each three phase group of fixed contacts on the busbar and circuit side, when the circuit breaker is removed. Padlocking facilities shall enable locking the two shutters to be locked in the closed position independently. The two shutter shall be Painted red and labelled with suitable warning symbols.

12-3-8 TESTING FACILITIES

The circuit breaker shall have a test position between the connected and disconnected Positions.

When in the test position, the circuit breaker shall be disconnected from the circuit and busbar contacts but still be positioned inside the cubicle. Low voltage plug shall remain connected in order to electrically operate the circuit breaker.

On the other hand, in order to carry out primary injection or insulation cable testing, provision shall be made for ready access to the cables without removing the shutters manually, Preferably in the shape of a removable testing truck.

12-3-9 CURRENT TRANSFORMERS

As far as the rated primary short circuit current and more generally the primary electrical characteristics of the circuit are concerned, the current transformers shall withstand at least the same current and voltage as the relevant switchgear. The current transformers shall be fitted on the circuit side except for the bus section panel.

Current transformers shall be epoxy resin cast type and shall fulfill the specification regarding the ratio. The accuracy class and the output each current transformer shall be chosen so as to ensure a good operation of the associated relays. instruments and meters.

The current transformers shall be labelled individually and type test certificates shall be provided when required.

12-3-10 VOLTAGE TRANSFORMERS

Voltage transformers shall be of the disconnectable type. They shall be protected on the primary side of high voltage fuses. It shall be possible to replace the fuses easily while the panel is energized. This operation shall be performed either from the front or from the rear of the cubicle. When circuit voltage transformers are required they shall be located at the rear of the cubicle just above the cable compartment. When busbar transformers are required they shall preferably be located in the bus section panel, possibly on each side of the busbars.

Voltage transformers shall be of the epoxy resin cast type. They shall be on one phase, connected phase to earth.

It shall be possible to padlock the voltage transformers in the disconnected position. Metallic shutters normally closed and, positively driven by the voltage transformers, shall open to enable the fuses to be replaced when the transformers are in disconnected position. These shutters shall shield the access to VT's as soon as they are connected. Auxiliary contacts shall be connected in series in the secondary circuits so as to open these circuits when the voltage transformers are in isolated Position.

The secondary windings shall be suitably insulated and shall be protected either by HRC fuses or preferably by MCB.

12-4 STANDBY GENERATING SET (…KV)

12-4-1 GENERAL

The emergency power switchboard and controls system will consist of engine generator control units, one master control unit with a synchronizing panel, and required distribution units. The units shall be bolted together to form one single line up of metal enclosed switchboards and controls, designed to properly interface with the number of remotely located load connection as shown on drawings. All equipment supplied shall be designed to meet all applicable NEMA, ANSI , IEEE and NFPA-76A, BSS standards

12-4-2 PRODUCTS

A Diesel Engine-Generator Set: diesel engine generator set. Generator set ratings: as shown on drawings at 0.8 PF, Prime rating, based on site conditions noted below. System voltage of: 13.8KV AC, Three phase, 60 hertz. Site Conditions: ambient temperatures up to 50 degrees C.

The generator set shall include inherent overcurrent, short circuit and overload protection, digital and analog AC metering equipment, sensor failure detection, and remote monitoring and control capability.

All necessary interface units and contacts to be provided.

B **Performance:**

Voltage regulation shall be +/- 0.5 percent for any constant load between no load and rated load.

Frequency regulation shall be isochronous from steady state no load to steady state rated load. Random frequency variation with any steady load from no load to full load shall not exceed plus or minus 0.25%.

The diesel engine-generator set shall be capable of single step load pick up of 100% nameplate kW and power factor, less applicable derating factors, with the engine-generator set at operating temperature.

C **Engine:**

The engine shall be diesel, . The horsepower rating of the engine at it's minimum tolerance level shall be sufficient to drive the alternator and all connected accessories. Two cycle engines are not acceptable. Engine accessories and features shall include:

An electronic governor system shall provide automatic isochronous frequency regulation. The engine governing system shall not utilize any exposed operating linkage.

Skid-mounted radiator and cooling system rated for full load operation in 50 degrees C ambient as measured at the generator air inlet. Radiator shall be provided with a duct adaptor flange.

An electric starter capable of three complete cranking cycles without overheating.

D. **AC Generator:**

The AC generator shall be; synchronous, four pole, 2/3 pitch, revolving field, drip-proof construction, single pre-lubricated sealed bearing, air cooled by a direct drive centrifugal blower fan, and directly connected to the engine with flexible drive disc.

All insulation system components shall meet NEMA MG1 temperature limits for Class H insulation system. Actual temperature rise measured by resistance method at full load shall not exceed 125 degrees Centigrade.

The generator shall be capable of delivering rated output (kVA) at rated frequency and power factor, at any voltage not more than 5 percent above or below rated voltage.

A permanent magnet generator (PMG) shall be included to provide a reliable source of excitation power for optimum motor starting and short circuit performance.

E **Engine-Generator Set Control:**

The generator set shall be provided with a microprocessor-based control system which is designed to provide automatic starting, monitoring, and control functions for the generator set. The control system shall also be designed to allow local monitoring and control of the generator set, and remote monitoring and control as described in this specification. The control shall be mounted on the generator set. The control shall be vibration isolated and prototype tested to verify the durability of all components in the system under the vibration conditions encountered. The control shall be UL508 labeled, and meet IEC8528 part 4. All switches, lamps and meters shall be oil-tight and dust-tight, and the enclosure door shall be gasketed. There shall be no exposed points in the control (with the door open) that operate in excess of 50 volts. The controls shall meet or exceed the requirements of IEC Std 801.2, 801.3., and 801.5 for susceptibility, conducted, and radiated electromagnetic emissions. The entire control shall be tested and meet the requirements of IEEE587 for voltage surge resistance. The generator set mounted control shall include the following features and functions:

F **Three position control switch labeled RUN/OFF/AUTO**.

In the RUN position the generator set shall automatically start, and accelerate to rated speed and voltage. In the OFF position the generator set shall immediately stop, bypassing all time delays. In the AUTO position the generator set shall be ready to accept a signal from a remote device to start and accelerate to rated speed and voltage.

G **Red "mushroom-head" push-button EMERGENCY STOP switch.**

Depressing the emergency stop switch shall cause the generator set to immediately shut down, and be locked out from automatic restarting.

H **Push-button RESET switch**.

The RESET switch shall be used to clear a fault and allow restarting the generator set after it has shut down for any fault condition.

I **Push-button PANEL LAMP switch.**

Depressing the panel lamp switch shall cause the entire panel to be lighted with DC control power. The panel lamps shall automatically be switched off 10 minutes after the switch is depressed, or after the switch is depressed a second time.

J **Generator Set AC Output Metering:**

The generator set shall be provided with a metering set with the following features and functions:

Digital metering set, 0.5% accuracy, to indicate generator RMS voltage and current, frequency, output current, output KW, KW-hours, and power factor. Generator output voltage shall be available in line-to-line and line-to-neutral voltages, and shall display all three phase voltages (line to neutral or line to line) simultaneously.

K **Generator Set Alarm and Status Message Display**:

The generator set shall be provided with alarm and status indicating lamps to indicate non-automatic generator status, and existing alarm and shutdown conditions. The lamps shall be high-intensity LED type. The lamp condition shall be clearly apparent under bright room lighting conditions. The generator set control shall indicate the existence of the following alarm and shutdown conditions on a digital display panel:

low oil pressure (alarm)
low oil pressure (shutdown)
oil pressure sender failure (alarm)
low coolant temperature (alarm)
high coolant temperature (alarm)
high coolant temperature (shutdown)
engine temperature sender failure (alarm)
low coolant level (alarm or shutdown-selectable)
fail to crank (shutdown)
overcrank (shutdown)
overspeed (shutdown)
low DC voltage (alarm)

high DC voltage (alarm)
weak battery (alarm)
low fuel-daytank (alarm)
high AC voltage (shutdown)
low AC voltage (shutdown)
under frequency (shutdown)
over current (warning)
over current (shutdown)
short circuit (shutdown)

ground fault (alarm)(optional-when required by code or specified)
over load (alarm)
emergency stop (shutdown)

L **Engine Status Monitoring:**

The following information shall be available from a digital status panel on the generator set control :

engine oil pressure (psi or kPA)
engine coolant temperature (degrees F or C; Both left and right bank temperature shall be indicated on V-block engines.)
engine oil temperature (degrees F or C)
engine speed (rpm)
number of hours of operation (hours)
number of start attempts
battery voltage (DC volts)

M **Control Functions:**

The control system shall include an engine governor control, which functions to provide steady state frequency regulation as noted elsewhere in this specification. The governor control shall include adjustments for gain, damping, and a ramping function to control engine speed and limit exhaust smoke while the unit is starting. The governor control shall be suitable for use in paralleling applications without component changes.

The control system shall include time delay start (adjustable 0-300 seconds) and time delay stop (adjustable 0-600 seconds) functions.

The control system shall include sender failure monitoring logic for speed sensing, oil pressure, and engine temperature which is capable of discriminating between failed sender or wiring components, and an actual failure conditions.

N **Alternator Control Functions:**

The generator set shall include an automatic voltage regulation system which is matched and prototype tested with the governing system provided.

The voltage regulation system shall include provisions for reactive load sharing and electronic voltage matching for paralleling applications.

Controls shall be provided to monitor the output current of the generator set and initiate an alarm when load current exceeds 110% of the rated current of the generator set on any phase for more than 60 seconds. The controls shall shut down and lock out the generator set when output current level approaches the thermal damage point of the alternator.

Controls shall be provided to monitor the KW load on the generator set, and initiate an alarm condition when total load on the generator set exceeds the generator set rating for in excess of 5 seconds.

Controls shall include a load shed control, to operate a set of dry contacts (for use in shedding customer load devices) when the generator set is overloaded .

An AC over/under voltage monitoring system which responds only to true RMS voltage conditions shall be provided. The system shall initiate shutdown of the generator set when alternator output voltage exceeds 110% of the operator-set voltage level for more than 10 seconds, or with no intentional delay when voltage exceeds 130%. Under voltage shutdown shall occur when the output voltage of the alternator is less than 85% for more than 10 seconds.

A battery monitoring system shall be provided which initiates alarms when the DC control and starting voltage is less than 25VDC or more than 32 VDC. During engine starting, the low voltage limit shall be disabled, and if DC voltage drops to less than 14.4 volts for more than two seconds a "weak battery" alarm shall be initiated.

When required by National Electrical Code or indicated on project drawings, the control system shall include a ground fault monitoring relay. The relay shall be adjustable from 100-1200 amps, and include adjustable time delay of 0-1.0 seconds. The relay shall be for indication only, and not trip or shut down the generator set.

O **Control Interfaces for Remote Monitoring**:

All control and interconnection points from the generator set to remote components shall be brought to a separate connection box. No field connections shall be made in the control enclosure or in the AC power output enclosure.

P **Base:**

The engine-generator set shall be mounted on a heavy duty steel base to maintain alignment between components.

Q **Generator Set Auxiliary Equipment and Accessories:**

Engine mounted, thermostatically controlled, water jacket heater(s) for each engine. The heater(s) shall be sized as recommended by the generator set manufacturer.

Vibration isolators, spring/pad type, quantity as recommended by the generator set manufacturer.

Base frame shall have for lifting points.

The generator set shall be vibrationally isolated from structure on spring type antivibration mountings. There shall be no rigid connections between the generator set and the structure.

Starting and Control Batteries: Starting battery bank, lead calcium type, 24 volt DC, sized as recommended by the generator set manufacturer, shall be supplied for each generator set with battery cables and connectors.

Battery Charger: A UL listed/CSA certified 10 amp voltage regulated battery charger shall be provided for each engine-generator set. Input AC voltage and DC output voltage shall be as required. Chargers shall be equipped with float, taper and equalize charge settings.

Analog DC voltmeter and ammeter, 12 hour equalize charge timer, AC and DC fuses shall also be provided on the charger.

12-4-3 **COUPLING SYSTEM**

The coupling system shall be of unit construction which forms the engine and generator into one unit of exceptional strength and ensures perfect alignment.

The alternator end shield and the engine flywheel housing faces shall be fully machined with spigots concentric to their shafts. The machined flanges mounted on the alternator shall be connected to the flywheel housing flange by steel bolts.

A flexible rubber block coupling shall be fitted between the engine and alternator to provide the drive and absorb the transmission of shock loads. The torsional flexibility shall be designed to match the torsional characteristics of the system to prevent resonant conditions.

12-4-4 **MUFFLER**

Exhaust muffler(s) shall be provided for each engine, size and type as recommended by the generator set manufacturer. Exhaust system shall be installed according to the generator set manufacturers recommendations and applicable codes and standards. Exhaust pipe shall have sufficient size to ensure that exhaust back pressure does not exceed the maximum limitations set by supplier.

Flexible gastight connection pieces shall be provided in the exhaust pipe line to allow for thermal expansion and to prevent vibration being transmitted to the engine.

A clearance hole shall be allowed where exhaust pipe passes through a wall to avoid over heating.

12-4-5 **FUEL STORAGE**

The fuel storage system with individual day tank sufficient for … hours operation of set on full load shall be provided. The day tank shall be piped to the generator set, with all necessary valves and flexible connections. For detailed specification of day fuel storage tanks, refer to relevant mechanical specifications.

12-4-6 **PRODUCT**

PARALLELING EQUIPMENT DESCRIPTION:

A Equipment Ratings:

The paralleling switchgear shall be rated for operation at voltage as shown on the contract drawings.

B Control Equipment Construction:

Switchgear shall be a rigid, free-standing, metal enclosed structure, designed for front access only. Each section of the switchgear shall be constructed with a minimum 12 gauge steel sheet metal framework.

Each section of the paralleling control system shall be labeled, including all covers, barriers, and supports. Individual control sections shall be isolated from each other by metal or insulating barriers.

All wiring shall be 105 degree C , 600 volt rated, and sized as required. Each wire, device or function shall be suitably identified by silk-screen or similar permanent identification.

The busbar shall be copper with bolted joints for all three phases, with a full neutral, and a 1/4 x 2 inch ground bus extending through all sections. Bus shall be braced for peak symmetrical amperage available from all generator sets plus motor contributions to 50,000 amps RMS minimum.

The framework and all other sheet metal components of the system shall be primed with a rust-inhibiting primer, and finished with two coats of satin finish gray enamel.

All door mounted control devices shall be industrial type oil-tight with contact ratings a minimum of twice the maximum circuit ampacity they are controlling. Toggle switches and other light duty control devices are not acceptable. Indicator lamps shall be high intensity LED type devices. Indicator lamp condition (on or off) shall be easily visible in bright room lighting conditions.

All field interconnecting wiring shall be sized as specified by system manufacturer and shall be stranded.

C Control Power:

Control power for the system shall be derived from the generator set 24VDC starting batteries. A solid state, no break "best battery" selector system shall be provided so that control voltage is available as long as any battery bank in the system is available, and that all battery banks are isolated to prevent the failure of one battery from disabling the entire system. Generator set governing, voltage regulation, load sharing, synchronizing, protection, and control equipment shall be capable of proper operation with battery voltage levels down to 8VDC.

D GENERATOR SET PARALLELING CONTROL PANELS (IEC 439-1 Form 2)

Provide a paralleling control panel for each generator set in the emergency power system. The paralleling control functions may be integrated with the generator set control functions (with duplicate feliminated). Each paralleling control panel shall contain the components and devices as described in this section.

i) Front Display Panel:

The front panel of the paralleling control shall contain the following instruments and devices:

a) 1% accuracy generator set AC output instruments; Ammeter, Voltmeter, Frequency Meter, Wattmeter, KW-hour meter, Power Factor Meter. Selector switches to allow viewing of voltage and amperes for each phase shall be provided. For 3-phase/4-wire systems the voltmeter shall indicate line to line and line to neutral conditions. Voltmeter and frequency meter shall be analog instruments.

b) Running Time Meter, Start Counter

c) Generator Set Mode Selector Switch: Switch shall provide run, off, and automatic functions for control of the generator set.

d) Breaker trip/close switch with breaker status indicating lamps. The switch shall be interlocked with the control system such that breaker closure is not possible unless the mode select switch is in the run position and the generator set is synchronized with the system bus.

e) Control Reset push-button switch with indicating lamp. Lamp shall flash to indicate that generator set is locked out due to a fault condition.

f) Lamp test push-button switch. Operation of this switch shall cause all lamps on the panel to be simultaneously tested.

g) The control panel shall be provided with a set of DC-powered lamps with a switch to allow viewing of all functions on the front panel when normal lighting systems are not available.

h) Emergency Stop switch. The emergency stop switch shall be a red, mushroom head switch which maintains it's position until manually reset.

i) Precision voltage and frequency adjust raise/lower switches. Switches shall allow the generator set frequency and voltage to be adjusted plus or minus 5% when the generator set is operating independently of the system bus. Voltage and frequency adjustment switches shall be located adjacent to the generator set and bus metering, synchroscope and manual paralleling panel, for ease of use by the operator.

j) Alarm and status indicating panel to indicate the following conditions (alarm horn shall be located on master control) :

Function	Lamp Color	Alarm Horn	Shutdown Unit
Low DC Voltage	Amber	*	
High DC Voltage	Amber	*	
Weak Battery	Amber	*	
Fail to Sync	Amber	*	
Low Oil Pressure Alarm	Amber	*	
Low Fuel - daytank	Amber	*	
High Engine Temp Alarm	Amber	*	
Spare (2)	Amber	*	
Ground Fault (when required)	Amber	*	
Overcurrent Alarm	Amber	*	
Breaker Failure	Red	*	*
Not in Auto	Red	*	*
High Engine Temp	Red	*	*
Low Oil Pressure	Red	*	*

Overcurrent	Red	*	*
Short Circuit	Red	*	*
Loss of Excitation	Red	*	*
Reverse Power	Red	*	*
Overcrank	Red	*	*
Overspeed	Red	*	*
Under Frequency	Red	*	
Under Voltage	Red	*	*
Over Voltage	Red	*	*
Phase Rotation	Red	*	*
Low Coolant Level	Red	*	*
Automatic	Green		
Generator Running	Green		
Breaker Open	Green		
Breaker Closed	Green		
Demand Mode Standby			
Timing for Start			
Timing for Shutdown			

Provide all other components required, such as properly sized current transformers, transducers, terminal blocks, etc., for reliable system operation, as described herein under "SYSTEM OPERATION".

ii) Paralleling Control Panel, Internal Components:

a) Electrically operated power circuit breaker with electronic trip unit (long, and instantaneous trips) in fixed or drawout frame. Frame size and trip units shall be as shown on the project drawings.

b) Electronic isochronous kW load sharing control to operate the engine governors during synchronizing and to provide isochronous load sharing when paralleled. The control system shall allow sharing of real kW load between all generator sets in the system to within 5% of equal levels, without introduction of frequency droop into the system. The control system shall include provisions for kW load sharing with an infinite bus.

c) The isochronous load sharing module and engine governor shall be a coordinated system of a single manufacturer.

d) Electronic isochronous kVAR load sharing control to operate the alternator excitation system while the generator set is paralleled.

f) Synchronizer to electronically adjust the engine governor to match the voltage, frequency and phase angle of the bus. Synchronizer shall maintain the engine-generator voltage within 1% of bus voltage and phase angle within 20 electrical degrees of the bus for 0.5 seconds before circuit breaker closing. Each unit shall have its own synchronizer; systems using

a switching scheme to utilize a single system synchronizer will not be approved.

g) Controls shall include three phase sensing reverse power equipment, to prevent sustained reverse power flow into the generator set. When the reverse power condition exceeds 10% of the generator set kW for 3 seconds, the paralleling circuit breaker shall be tripped open and the generator shut down.

h) Controls shall be provided to verify generator set and bus phase rotation match prior to closing the paralleling breaker.

i) Electronic alternator overcurrent alarm and shutdown protection.

j) Electronic alternator short circuit protection.

E Master Control

Provide a master control to monitor and control the operation of the entire paralleling system. The master control panel shall contain the components described in this section.

i) Master Control Front Panel

The front panel of the master control shall contain the following instruments and devices.

a) 1% accuracy True RMS digital instruments to monitor total output of bus: Ammeter, Voltmeter, Frequency Meter, Wattmeter, Varmeter, Power Factor Meter, kW-Hour Meter, kW demand, kVAR hours, kVA hours. Selector switches to allow viewing of voltage and amperes for each phase shall be provided. For 3-phase/4-wire systems the voltmeter shall indicate line to line and line to neutral conditions.

b) Operator Interface Panel. An operator interface panel shall be provided which allows the operator to monitor and control the following functions:

General System Status: A graphic status panel shall be provided which indicates Generator set and bus configuration; genset designation and KW rating; generator set and bus energized/de-energized indication; generator set mode generator set alarm status (normal/warning/shutdown); paralleling breaker designation and status (open/closed/tripped); utility main and feeder breaker status for breakers controlled by this system.

F PARALLELING/DISTRIBUTION POWER SWITCHBOARD

i) Switchboard Ratings:

The paralleling/distribution power switchboard shall be designed as shown on the contract drawings, and rated for operation at voltage and current levels as shown on the contract drawings (Refer to main distribution switchboard specifications).

ii) Modes of Operation**:**

a) **Automatic Operation**

The normal mode of system operation shall provide for unattended automatic emergency paralleling of all engine gnerator sets, transfer of load, and load control for the entire emergency power system. Emergency power shall be supplied to the system emergency loads within 10 seconds after interruption of the normal service. Upon receiving a signal of failure of normal power, the system control unit will signal all engine generators to start. Each engine geneator will automatically start, and the first generator to achieve 90% of rated voltage and frequency will automatically connect to the emergency bus, via the generator circuit breaker. Generators with improper voltage or frequency shall not be permitted to connect to the bus untill the abnormality is corrected. As the remaining generators achieve proper operating conditions, the automatic synchroniser of each generator control unit will rapidly force them into synchronism with the bus, by sending correction signals to the electronic governor of each engine generator. After proper synchronism is attained, each engine generator will be automatically shared between all generators connected to the bus.

The transfer of load from normal to emergency bus shall be controlled by the system controls and shall occur in accordance with an established load control program through independent controller or combined with the centralised monitoring and control system. The program shall assign priority level to each load. The highest priority load shall be the first to transfer to the emergency bus. The first load transfer shall occur only after adequate generating capacity is connected to the bus.

Once normal power has returned and been determined stable, the transfer switch loads connection contactors or breakers and load shedding contactors will signal a return to the normal source. After all loads have transferred load back to the normal source, the engine generators will run unloaded for a short cooldown period (adjustable 0-15 minutes) and then shut down. The emergency power system circuitry shall then automatically reset and remain in readiness for the next failure of normal power.

b) **Manual Operation**

The emergency power system shall have the capability of being manually operated. Each generator set may be individually started by engine control switches located on the respective engine generator control units. Once started and stable, the generator may be manually connected to the emergency as

through individual generator circuit breakers. After the emergency bus is energised by the first generator, each remaining generator may be connected to the bus by utilizing permissive paralling circuitry.

12-4-7 **SHOP DRAWINGS**

The Contractor shall submit shop drawings for the Generator set including all necessary civil work details, such as trenches, concrete bases, etc.., Generator starting characteristics and manufacturers approval for the generator's correct selection as to connected load, derating factors, etc.., wiring diagrams and description of operation.

A copy of these shop drawings shall also be sent to the local power authorities for approval.

Any modifications required by the Engineer or the local power authorities to allow the equipment to comply with the codes, standards and specifications called for hereinbefore shall be carried out with no extra load.

12-5 AUTOMATIC CLOSED – TRANSITION TRANSFER AND BY-PASS – ISOLATION SWITCHES (ATS/BPS)

PART 1 GENERAL

12-5-1 Scope

A. Furnish and install automatic transfer & bypass-isolation switch with number of poles, amperage, voltage, and withstand current ratings as shown on the plans. Each Transfer/Bypass system(s) shall consist of a closed transition transfer switch and a two-way bypass/isolation switch. All switches and control modules shall be the product of the same manufacturer and shall have the possibility to be integrated within Main Distribution Switchboard.

B. The ATS/BPS shall transfer the load without interruption (closed transition) by momentarily connecting both sources of power only when both sources are present and acceptable. The maximum interconnection time is 100 milliseconds. The ATS shall operate as a conventional break-before-make (open transition) switch when the power source serving the load fails. Designs that transfer in a delayed transition manner (intentional delay in the neutral position) when closed transition transfer is bypassed are not acceptable.

12-5-2 Codes and Standards

The automatic closed transition transfer & bypass-isolation switches and accessories shall conform to the requirements of:

A. UL 1008 - Standard for Transfer Switch Equipment

B. IEC 947-6-1 Low-voltage Switchgear and Controlgear; Multifunction equipment; Automatic Transfer Switching Equipment

C. NFPA 70 - National Electrical Code

D. NFPA 99 - Essential Electrical Systems for Health Care Facilities

E. NFPA 110 - Emergency and Standby Power Systems

F. IEEE Standard 446 - IEEE Recommended Practice for Emergency and Standby Power Systems for Commercial and Industrial Applications

G. NEMA Standard ICS12-1993 (formerly ICS2-447) - AC Automatic Transfer Switches

H. UL 508 Industrial Control Equipment

12-5-3 Acceptable Manufacturers

ASCO, or approved equal

PART 2 PRODUCTS

12-5-4 **Mechanically Held Transfer Switch**

A. The transfer switch shall be electrically operated and mechanically held. The electrical operator shall be a momentarily energized, solenoid mechanism. Main operators which include overcurrent disconnect devices, linear motors or gears shall not be acceptable. The switch shall be mechanically interlocked to ensure only two possible positions, normal or emergency.

B. All transfer switch sizes shall use only one type of main operator for ease of maintenance and commonality of parts.

C. The switch shall be positively locked and unaffected by momentary outages, so that contact pressure is maintained at a constant value and contact temperature rise is minimized for maximum reliability and operating life.

D. All main contacts shall be silver composition. Switches rated 600 amperes and above shall have segmented, blow-on construction for high withstand and close-on capability and be protected by separate arcing contacts.

E. Inspection of all contacts shall be possible from the front of the switch without disassembly of operating linkages and without disconnection of power conductors. Switches rated 600 amps and higher shall have front removable and replaceable contacts. All stationary and moveable contacts shall be replaceable without removing power conductors and/or bus bars.

F. Designs utilizing components of molded-case circuit breakers, contactors, or parts thereof, which are not intended for continuous duty, repetitive switching or transfer between two active power sources are not acceptable.

G. Where neutral conductors are to be solidly connected as shown on the plans, a neutral conductor plate with fully rated AL-CU pressure connectors shall be provided.

12-5-5 **Bypass-Isolation Switch**

A. A two-way bypass-isolation switch shall provide manual bypass of the load to either source and permit isolation of the automatic transfer switch from all source and load power conductors. All main contacts shall be manually driven.

B. Power interconnections shall be silver-plated copper bus bar. The only field installed power connections shall be at the service and load terminals of the bypass-isolation switch. All control interwiring shall be provided with disconnect plugs.

C. The isolation handle shall provide three operating modes: "Closed," "Test," and "Open." The "Test" mode shall permit testing of the entire emergency power system, including the automatic transfer switches with no interruption of power to the load. The "Open" mode shall completely isolate the automatic transfer switch from all source and load power conductors. When in the "Open" mode, it shall be possible to completely withdraw the automatic transfer switch for inspection or maintenance to conform to code requirements without removal of power conductors or the use of any tools.

D. When the isolation switch is in the "Test" or "Open" mode, the bypass switch shall function as a manual transfer switch.

E. Designs requiring operation of key interlocks for bypass isolation or ATSs which cannot be completely withdrawn when isolated are not acceptable.

12-5-6 **Microprocessor Controller**

A. The controller's sensing and logic shall be provided by a single built-in microprocessor for maximum reliability, minimum maintenance, and the ability to communicate serially through an optional serial communication module.

B. A single controller shall provide twelve selectable nominal voltages for maximum application flexibility and minimal spare part requirements. Voltage sensing shall be true RMS type and shall be accurate to ± 1% of nominal voltage. Frequency sensing shall be accurate to ± 0.2%. The panel shall be capable of operating over a temperature range of -20 to +60 degrees C and storage from -55 to +85 degrees C.

C. The controller shall be connected to the transfer switch by an interconnecting wiring harness. The harness shall include a keyed disconnect plug to enable the controller to be disconnected from the transfer switch for routine maintenance. Sensing and control logic shall be provided on multi-layer printed circuit boards. Interfacing relays shall be industrial grade plug-in type with dust covers. The panel shall be enclosed with a protective cover and be mounted separately from the transfer switch unit for safety and ease of maintenance. The protective cover shall include a built-in pocket for storage of the operator's manuals.

D. All customer connections shall be wired to a common terminal block to simplify field-wiring connections.

E. The controller shall meet or exceed the requirements for Electromagnetic Compatibility (EMC) as follows:

1. IEEE472 (ANSI C37.90A) Ring Wave Test.
2. ENC55011 1991 Class A Conducted and Radiated Emission.
3. EN61000-4-2 Electrostatic Discharge Immunity, Direct Contact & Air Discharge.
4. EN61000-4-3 Radiated Electromagnetic Field Immunity.
5. EN61000-4-4 Electrical Fast Transient Immunity.
6. EN61000-4-5 Surge Immunity.
7. ENV50141 HF Conducted Disturbances Immunity.

12-5-7 **Enclosure**

A. The ATS/BPS shall be furnished in a NEMA type 1 (IP 40) enclosure.

B. All standard and optional door-mounted switches and pilot lights shall be 16-mm industrial grade type or equivalent for easy viewing & replacement. Door controls shall be provided on a separate removable plate, which can be supplied loose for open type units.

PART 3 OPERATION

12-5-8 Controller Display and Keypad

A. A four line, 20 character LCD display and keypad shall be an integral part of the controller for viewing all available data and setting desired operational parameters. Operational parameters shall also be available for viewing and limited control through the serial communications input port. The following parameters shall only be adjustable via DIP switches on the controller:

1. Nominal line voltage and frequency
2. Single or three phase sensing
3. Operating parameter protection
4. Transfer operating mode configuration (Open transition, Closed transition or Delayed transition)

All instructions and controller settings shall be easily accessible, readable and accomplished without the use of codes, calculations, or instruction manuals.

12-5-9 Voltage, Frequency and Phase Rotation Sensing

A. Voltage and frequency on both the normal and emergency sources shall be continuously monitored.

B. Repetitive accuracy of all settings shall be within ± 0.5% over an operating temperature range of -20°C to 60°C.

C. Voltage and frequency settings shall be field adjustable in 1% increments either locally with the display and keypad or remotely via serial communications port access.

D. Source status screens shall be provided for both normal and emergency to provide digital readout of voltage on all three phases, frequency and phase rotation.

12-5-10 Time Delays

A. An adjustable time delay of 0 to 6 seconds shall be provided to override momentary normal source outages and delay all transfer and engine starting signals. Capability shall be provided to extend this time delay to 60 minutes by providing an external 24 VDC power supply.

B. A time delay shall be provided on transfer to emergency, adjustable from 0 to 60 minutes, for controlled timing of transfer of loads to emergency.

C. An adjustable time delay of 0 to 6 seconds to override momentary emergency source outage to delay all retransfer signals during initial loading of engine generator set.

D. Two time delay modes (which are independently adjustable) shall be provided on re-transfer to normal. One time delay shall be for actual normal power failures and the other for the test mode function.

E. A time delay shall be provided on shut down of engine generator for cool down, adjustable from 0 to 60 minutes.

F. The controller shall also include the following built-in time delays for Closed Transition Transfer with Bypass-Isolation operation:

1. 1 to 5 minute time delay on failure to synchronize normal and emergency sources prior to closed transition transfer.
2. 0.1 to 9.99 second time delay on an extended parallel condition of both power sources during closed transition operation.

12-6 MAIN DISTRIBUTION SWITCHBOARD

12-6-1 GENERAL

The Contractor shall supply and install the main distribution switchboard(s) fed from transformers as shown on the Drawings and as herein specified. The equipment shall include busbars, fully motorized and withdrawable circuit breakers and/or switch fuses, instruments, ammeters, voltmeters and all necessary parts to install a complete distribution switchboard, as shown on the Drawings and as herein specified.

These specifications also cover the main synchronizing switchboard of the generators MDS-GEN.

This specification relates to Type Tested Assemblies (TTA) and Partially Type Tested Assemblies (PTTA). In accordance with IEC 439-1 Standard.

The switchboard shall be suitable for operating on 3 phase, 4 wire, 380 volts, 60 Hz supply.

The symmetrical fault rating shall be 50 KA for ***1 second***. The switchboard shall be ASTA tested at the fault; copies of the test certificates shall be submitted for Engineer's approval.

The main breaker shall be Air circuit breaker withdrawable, Hand charged spring, 3 poles:

ICW = 50kA for ***1*** seconds
Safety shutter
4 auxiliary contacts - ON/OFF signaling status
2 Alarm auxiliary contacts

All the branch circuit breakers shall be Molded Case type, fixed, and with number of poles as indicated on the drawings, with the following features:

ICS = 50kA.
2 auxiliary contacts - ON/OFF signaling status
1 Alarm auxiliary contacts

The arrangement of the equipment within the assemblies shall be individually-mounting type in a modular arrangement and shall be such as to afford maximum accessibility to all parts, incoming and outgoing wires and cables.

The main distribution switchboard shall be factory built assembly, metal clad, totally enclosed box type, tested at the factory, complying with B.S. 5486/IEC 439-1.

Over voltage protection shall be provided at incoming feeder entry point and shall be coordinated with over voltage protection located down stream at entry point of feeder of panel fed directly from main switchboard.

Main steel work should be electrozinc plated and passivated followed by stoved powder, finish colour shall be RAL 7032.

The switchboard shall comply with:

- IEC 439-1
- EN 60 439-1
- BS EN 60 439-1
- VDE 0660 part 500
- DIN EN60 439-1 Part 1.
- Salt mist test of IEC 68.2.30

Compartment of circuit breakers shall be finished in white. Fasteners shall be zinc plated and bronze passivated.

The Contractor must at an early stage provide the Engineer with all the necessary manufacturer's details and shop drawings concerning the assembly to allow him to check the design of the concrete structure, particularly concerning the loads, the overall dimensions and the cable grouting holes.

Switchboards shall be manufactured by Cutler Hammer (USA), ABB (Italy), Merlin Gerin (France), Kloekner Moeller (Germany), Square D (UK), Siemens (Germany), or approved equal.

12-6-2 CONSTRUCTION OF THE ASSEMBLY

The assembly shall be of the indoor gasketed type of size, rating and arrangement as indicated on the Drawings. The complete assembly shall be ground mounting type with matching cases to form continuous internal structures.

The assembly shall consist of a completely enclosed self supporting metal structure, containing circuit protective devices and all other associated equipments as indicated on the Drawings and/or specified under other Clauses.

The assembly shall consist of the required number of formed and welded electrozincated sheet steel enclosures required to mount circuit protective devices and other equipments.

The metal sheets that are in close proximity of high currents shall be made of aluminium.

Front, side and top plates shall be steel, removable and not less than 2 mm thickness.

All fastenings between structural members shall be bolted, not welded to provide flexibility during installation.

A modular individual mounting arrangement shall be used to permit interchanging different sized device cover plates without additional drilling of structure.

Structure and buses shall be arranged to permit future sections to be added to the left and right sides. Suitable cover plate must be provided for temporary protection. The assembly shall be vermin and rodent proof. Protection shall be to IP 41, as a minimum requirement.

The complete switchboard, after assembly shall be tested for operation under simulated service conditions to assure the accuracy of the wiring and the functioning of all equipment.

Padlocking latch shall be used to lock the drawer in the racked out position.

12-6-3 **BUSBARS**

Main horizontal busbar ratings as shown on the Drawings shall be provided across the top of each structure. Each structure shall also be complete with vertical copper buses to distribute incoming power to each outgoing protective device in the structure.

All bus connections shall be bolted and clamp type terminals provided for cables.

All bus work and connections shall be accessible for inspection and maintenance purposes.

Neutral shall be full size, unless otherwise indicated.

The short time with stand current shall be 80 KA rms.

Earthing bus shall be sized not less than 240 mm2 in cross-section earthing bus shall extend throughout the entire length of the assembly.

All buses and connections of the switchboard shall consist of high conductivity copper bars mounted on heavy duty glass polyester supports to BS 159.

The bus shall be electrolytic copper of the CU ETP type (ISO 1337) and of sufficient cross-sectional area to continuously conduct rated current with a maximum average temperature rise of 20 ^{o}C above an ambient temperature of 50 ^{o}C.

12-6-4 INSTRUMENTS AND METERS

The Contractor shall provide instruments, instrument transformers and selector switches as shown on the Drawings. The Contractor shall otherwise provide three ammeters with current transformers and one voltmeter with 7 position selector switch for the main, and one maximum demand meter.

Instruments shall be digital type.

Instrument transformers shall be rated for 600 volt service with adequate thermal capacity and mechanical strength to match the short circuit caof the switchboard. Potential transformers primaries and secondaries shall be protected by fuses. Primary fuses shall be current limiting.

12-6-5 SHOP DRAWINGS

The Contractor shall submit shop drawings for the switchboards including schematic diagrams with all protective devices, control, instruments and instrument transformers details, dimensions of the assembly, etc. A copy of these shop drawings shall also be submitted to the local power authorities for approval. Any modification required by the Engineer or the local power authorities to allow the equipment to comply with the codes, standards and specifications called of hereinbefore shall be carried out without additional charges.

12-7 LOW VOLTAGE AIR CIRCUIT BREAKER

12-7-1 LV AIR CIRCUIT BREAKER

the circuit breakers shall comply with IEC947.2 or corresponding standards in member countries (VDE 0660: BS 4752: UTE C63120): optional version may comply with UL/ANSI/JIS standard.

the breaking capacity performance certificates shall be available for category B to the above mentioned standards. The test shall be carried out with a breaking performance during operation (Ics) equal to the ultimate breaking capacity (Icu).

all circuit breakers can be reverse fed without reduction in performance.

All breakers shall be with drawable.

all circuit breakers shall have a rated operational voltage of 690V AC (50/60Hz).

the rated insulation voltage shall be 1000 V AC (50/60 Hz).

all circuit breakers shall fully tropicalized (T2) as standard.

The circuit breaker shall comply with the isolating function requirements of IEC 947-2 section 7.1.2.

All breakers shall be equipped with necessary contacts and control devices for connection and monitoring.

Minimum electrical endurance: 10000 operations

12-7-2 CONSTRUCTION

They shall be available in fixed or drawout models and in 3-poles or 4-poles versions as indicated on drawing.

The required safety clearance around the air circuit breaker may be canceled by adding protective covers. Type tests shall be achieved with the minimum safety clearance.

All air circuit breakers shall be designed to be maintained; in order to reduce maintenance, electrical endurance characteristics shall be very high.

On 4-pole version, the neutral pole shall have the same current rating as the other poles.

All air circuit breakers main contact shall be encased in a reinforced polyester casing and offer double insulation from the operators on the breaker front face. The circuit breaker also shall offer total insulation of the control part with respect to the power part.

Operating Mechanism

The operating mechanism shall be of the spring type with a closing time of less than or equal to 80 ms.

There shall be 2 types of spring charging, either:

Hand charged spring where the springs are wound only by hand or:

- Motor charged spring, where the springs are automatically charged by an electric motor. The maximum time to charge the springs shall not exceed 4 seconds. It shall also be possible to charge the springs manually.

Arc Chutes

Arc chutes shall be common on the whole range and removable on site to allow inspection of arc chutes and main contact.

Drawout Mechanism

General

The drawout operation shall be possible through a closed door.

Three positions of the moving part shall be possible:

1- Connected position - all auxiliary and main circuits engaged.

2- Test position - all auxiliary circuits engaged all main circuits disconnected.

3- Isolated position - all circuits disconnected.

Safety Requirements

A door interlock shall be provided so that it shall not be possible to open the door until the air circuit breaker moving part is in the disconnected position.

Mechanical Indicators

Mechanical indication on the front of the air circuit breaker shall be provided to indicate the following:

1- Main contacts closed "ON".
2- Main contacts open "OFF".
3- Springs charged.
4- Springs discharged.
5- Circuit breaker in "connected" position (drawout only).
6- Circuit breaker in "test" position (drawout only).
7- Circuit breaker in "disconnected" position (drawout only).

All indicators must be clearly visible.

General Requirements

The overcurrent relay shall be a **solid state type**

It shall be micro-processor based and use digital programming techniques for highest protection accuracy.

and be **integrated as part of the circuit breaker**

- the sensors and the wiring shall be integrated within the case.
- the overcurrent relay shall be self powered.
- the current sensors shall be located within the case of the circuit breaker.

The control unit shall be equipped with a push to reset mechanical indicator, for anti-pumping function.

The control unit may communicate with other equipment on a communication BUS.

12-8 UNDERGROUND DISTRIBUTION SYSTEM

12-8-1 General

The Contractor shall supply, install and connect a complete underground distribution system as shown on the Drawings and as herein specified.

General routing of the underground distribution system shall be adhered to, except that any interferences with other trades or with existing underground installation shall be brought to the attention of the Engineer.

Underground distribution shall be either directly buried or in concrete duct banks as specified or shown on the Drawings. Roadway crossings shall in any case be in concrete duct banks.

Manholes and handholes shall be used as required and/or as indicated.

Concrete used shall be class A.

12-8-2 Ducts

Ducts shall have the following specifications:

- Nominal size (in)(mm) — Wall thickness
  - 2 — 1.5
  - 3 — 2.5
  - 4 — 2.9
- Material : PVC
- Specific gravity : 1.4
- Vicat softening point : 82C to BS 2782
- Inflammability : not to support combustion
- Tensile strength : 6750 PSI at 20C
- Impact strength : 3.5 ft-lb
- -Compressive strength : 9,500 PSI
- Flexural strength : 13,500 PSI

12-8-3 **Installation of Ductbanks**

Ductbanks shall be installed as indicated on Drawings and as specified. The Contractor shall provide all excavation and backfilling work.

Ducts shall be installed with a minimum slope of 0.5% and shall be sloped to manholes or handholes. Ducts shall slope away from buildings where possible.

Spacers shall be installed at intervals of approximately 120 cm and staggered between tiers of ducts to provide not less than 30cm of longitudinal separation. Base spacers shall provide at least 7.5cm between the bottom of the trench and the underside of the bottom conduits.

The space shall be completely filled with concrete. Conduits and spacers shall be firmly wired together before the concrete is placed.

Prior to the placing of the concrete, all sand, dirt and any other debris shall be removed from the trench. Conduits shall be held in place to prevent floating or accidental movement.

Joints in the conduits shall be staggered at 15 cm minimum. Couplings shall not rest on the bottom of the trench. Steel reinforcement shall be provided for all ductbanks under roadways.

Concrete encasement shall be installed so that a minimum clearance of 30cm is left between concrete and parallel pipes, structures, etc. Crossing ducts shall be spaced 15 cm as a minimum.

Top of the concrete shall not be less than 50 cm below the finished grade or paving except for high tension cables in which case it shall not be less than 80 cm.

Ducts shall be sealed at each end, with split teak wood plugs and bitumen or by other approved means to prevent the ingress of water and vermin.

20% spare ducts but not less than one shall be provided in each duct bank.

Where ductbanks are installed below the structural footing level of the building, it shall be the entire responsibility of the Electrical subcontractor to coordinate with the Civil subcontractor for the laying of the concrete duct bank prior to the installation and erection of the structural footing.

All necessary diversions and warning signs and/or alternative diversion routes shall be provided in case existing roads or graded defined tracks are temporarily blocked for execution of the work.

12-8-4 **Directly Buried Cables**

Directly buried cable shall be laid underground as shown on the Drawings and as herein specified.

Trenches shall be kept as straight as possible and shall be excavated to approved formations and dimensions. Trenches shall have vertical sides and shall be close timbered and strutted where necessary to prevent subsidence.

All unsuitable excavated material shall be removed from site.

All cables laid in the same trench shall be placed in the same horizontal plane leaving a space of at least 7.5cm except as otherwise shown on the Drawings and specified hereinafter.

Cable trench depth shall be as shown on layout drawings, with minimum depth of 100 cm for a single layer of HV cables. Minimum depth from the top of cables to finished grade, unless otherwise, indicated on layout drawings, shall be 50cm for LV power feeders, and 45cm for street lighting cables.

A red PVC strip marked 'DANGER' and as specified in the design specification shall be installed 100 mm above cable protection covers.

All cable or armour shall have links to earth to enable testing of sheath. Earth resistance shall not be greater than 10 ohms.

12-8-5 **Manholes and Handholes**

Manholes and handholes shall be constructed of class A concrete cast in place or of precast-concrete sections with leakproof joints.

Frames and covers shall be provided as indicated on the Drawings.

Manholes shall be provided with cable racks, hooks, pulling irons and other features as shown on the Drawings and as required.

A 15cm crushed-stone base shall be placed under each manhole and handhole.

Conduits entering manholes and handholes shall terminate in end bells.

Additional openings in manhole walls for future conduit entrance shall be provided where required or as indicated. Such openings shall be sealed with necessary courses of brick.

The exterior surfaces of all manholes and handholes shall be given two heavy coats of bituminous water proofing material.

12-8-6 **Cable Identification**

Cable Identification shall consist of :

a) Cable route and joint markers.
b) Identification markers of the cable itself.

Cable route and joint markers shall be placed at intervals of 50 metres and at points of route alignment changes and at both ends of road for road or pipe crossings. Cable trenches less than 100 cm side shall be provided with single markers on the center line of the run.

Trenches wider than 100cm shall be indicated by markers mounted on each side of the trench at the intervals specified.

Markers shall be 60 x 40 x 10cm class B concrete block with 2.5 chamfer around edges. The top of the markers shall be flush in paved areas, shall protrude 5cm in unpaved areas and 2cm in finished lawns.

The words "Electrical Ductbank" with directional arrows shall be impressed both in English and in Arabic on the markers used for ductbanks.

The words "Electrical Cables" shall be impressed both in English and in Arabic on the markers used for direct burial Cables.

Similar materials suitably inscribed shall be used to indicate the position of underground joints.

All power and control cables shall be provided with identification markers at their termination, and at points along the route at intervals of not more than 25 metres apart. Markers shall be made of permanent material of an approved type.

12-8-7 **Cable Records**

Records of cables shall be carefully taken on site during the execution of the works. The records shall show theroutes, the exact location of each cable, the position of joints and terminations, the date of jointing, weather conditions prevailing, the date of testing, the name of jointer, the lengths between joints, the serial number of cable drums, the direction of lay of cable, that is A to Z ends, and where more than one cable is laid, sectional insert of cable trench. Any other services that cross the route of the cable shall be recorded.

12-8-8 **Power Cables End Sealings**

Power cables terminating in cable pits shall be left slack at least 2 meters. Cable end sealing caps shall be used to terminate all cables in cable pits.

Sealing cap, shall be constructed of rubber with high density polyethylene ends, factory assembled onto removable collapsible cores supplied for site installation in a prestretched condition.

12-9 ELECTRICAL RACEWAY SYSTEMS

12-9-1 GENERAL

The Contractor shall furnish and install the complete raceway systems, with all accessories fittings, boxes etc., as indicated on the drawings, and as herein specified, in an acceptable and workmanlike manner.

Unless otherwise indicated, all raceways shall consist of rigid steel conduits which shall be installed exposed. In rooms where conduits are exposed to weather, raceways shall consist of polyvinyl chloride-coated (PVC-coated) rigid steel conduit. Where raceways run concealed, they shall be polyvinyl chloride conduit.

The interior of all raceways, fittings, and elbows shall have a smooth enamel or similar corrosion-resistant coating. The minimum size of rigid conduit shall be 5/8" inside diameter unless otherwise indicated or accepted.

Flexible conduit shall be used only where flexible connections are required at exposed expansion joints, or for short connections to vibrating or adjustable equipment.

12-9-2 DRAWING DIAGRAMMATIC

All raceway runs are shown diagrammatically to outline the general routing of the raceway.

The installation shall be made to avoid interfering with pipes, ducts, structural members, or other equipment. Should structural or other interference's prevent the installation of the raceways, or setting of boxes, cabinets, or other electrical equipment, as indicated on the drawings, deviations must be acceptable to the Engineer and after acceptance, shall be made without additional charge. The number of raceways shall not be less than that indicated on the drawings. Material and installation of raceways and related components shall be as hereinafter specified.

12-9-3 RIGID STEEL CONDUIT

Rigid steel conduit shall be supplied with a coupling on one end and a thread protector on the other. Conduit and threading shall be hot-dipped galvanized. All conduit dimensions shall conform to the requirements of ANSI Standards C80.1, C80.2 or C80.5 or shall conform to SASO, or as applicable.

12-9-4 PVC CONDUIT

PVC conduit for encasement in concrete or concealed in walls shall be type I and shall conform to industrial NEMA standard and carry a UL listing for underground encased use or equivalent.

12-9-5 FLEXIBLE METAL CONDUIT

Flexible metal conduit, fittings, size, and material shall match the rigid conduit to which it is connected, unless otherwise indicated. All flexible metal conduit shall be liquid tight.

Conduit shall consist of flexible, corrosion-resistant metal with a watertight synthetic jacket extruded over the conduit and a continuous copper ground under the jacket. Conduit shall conform to Underwriter's Laboratories Standard for Flexible Metal Conduit or equivalent.

12-9-6 BOXES

Standard, sheet-metal, outlet and junction boxes shall be constructed of code-gage, galvanized sheet steel. The size of each box shall not be less than that required by the National Electrical Code or equivalent. Boxes shall conform to the Underwriter's Laboratories Standard for Outlet Boxes and Fittings or equivalent. Boxes for installation in concrete shall be concrete tight. Shallow boxes shall not be used.

Exposed boxes for switches, receptacles and other devices shall be corrosion-resistant, cast-metal type ES and FD fittings with gasketed cast-metal cover-and stainless steel screws.

Outlet boxes and covers for use with PVC conduits shall be heavy gage PVC.

Telephone cabinets shall be constructed of code-gage galvanized steel with a hinged flush door.

12-9-7 FITTINGS

Fittings shall be installed to match the raceway being used. Fittings shall not be used to replace elbows and pull boxes, unless space or other problems make the use of fittings necessary. Oversize fittings shall be used whenever large cable is installed in order to maintain the proper radius.

Cast-iron fittings shall not be used unless they are made of malleable iron or a mixture of gray iron and cast steel.

The ends of all floor conduits installed for future use shall be terminated with couplings and readily removable plugs set flush with the finished floor surface. Spare wall conduits shall be capped at the wall where they enter a building.

The ends of all conduits shall be equipped with suitable conduit fittings. Conduits terminating at motor control center or power distribution equipment, or in a box above or below, shall be fitted with grounding type bushings, or shall be solidly grounded by locknuts or other approved fittings. Each grounding bushing shall be connected to the ground bus by a bare or green-covered copper wire. The size of the ground wire shall be not less than 2.5mm² shall be as required by the National Electrical Code or equivalent.

Conduits entering gasketed sheet-metal boxes or gasketed sheet-metal equipment enclosures shall terminate with gasketed hubs.

Conduits entering nongasketed sheet-metal boxes or enclosures shall be terminated with double locknuts and insulated bushings, or the equivalent thereof.

Where specific fittings are not mentioned in this specification, standard acceptable fittings shall be used. They shall be of the same material as the conduit or devices to which they are connected and shall comply with all necessary requirements.

12-9-8 SLEEVES

Sleeves shall be provided for exposed conduits or cables passing through interior floor slabs and walls.

Sleeves passing through floor slabs shall be flush with the bottom of the slab, extend approximately 25mm above the surface of the floor, and be watertight between sleeve and floor slab.

Sleeves used to contain aluminum conduit if any shall be of heavy polyvinyl chloride construction.

Sleeves passing through exterior walls and below grade shall be wall entrance seals of watertight construction. They shall be watertight between slab and sleeve and between sleeve and conduit and cable. These wall-entrance seals shall be of malleable iron with black paint finish and polyvinyl chloride sleeve, with a watertight sealing gland. Sealing gland design shall be such that they may be tightened any time after installation. Wall entrance seals shall have oversized sleeves of proper length to position the sealing-gland housings flush with the wall faces.

12-9-9 INSTALLATION OF RACEWAYS

Exposed raceways shall be galvanized steel type and shall be installed parallel or at right angles to walls and ceilings beams. All changes in direction shall be made as far as possible with approved bends, elbows, and pull boxes. The spacing between parallel runs shall be uniform throughout. Raceways shall be held securely in place by approved hangers and approved fasteners.

All metal raceways shall be fictively grounded by connection to properly grounded enclosures bonding or other acceptable means, to obtain a permanent low resistance path to ground throughout the installation. All raceway sections in a single run and in parallel runs shall be of the same type and finish.

Concrete anchors for installing boxes, conduit supports, lighting fixtures and other electrical equipment shall be stainless steel sleeve type anchors equivalent to Red Head manufactured by Phillips Drill Co. All nuts bolts, washers, etc., used with concrete anchors shall be stainless steel. Conduits shall be supported by hangers or pipe straps spaced according to the National Electrical Code or Equivalent, but on not more than 3m centers.

Galvanized conduit shall have galvanized supports.

Care shall be taken in the installation of polyvinyl chloride-gasketed conduit to prevent damage to the jacket. The manufacturer's recommendations shall be followed in the installation of the conduit, and repair of minor damage to the jacket. If extensive damage is present on the conduit, it shall be replaced as directed by the Engineer. All conduit terminations at boxes, cabinets, and other equipment, shall be made to welded hubs and enclosures covered with polyvinyl chloride in the manner previously specified for conduit coupling.

12-9-10 CONDUIT DRAINAGE

As far as practicable, the conduit shall be pitched to drain to outlet boxes, or otherwise installed so as to avoid trapping moisture. Trapped conduit in concealed locations shall be provided with accessible outlet boxes for drainage. Where dips are unavoidable in exposed conduits a fitting with a suitable drain hole shall be installed at the low point.

12-9-11 CONDUITS CONCEALED IN SLABS, WALLS & FLOORS

Conduits concealed in slabs, walls and floors shall be PVC type and shall be installed as close to the middle of the concrete slabs as practicable without disturbing the reinforcement. The outside diameter shall not exceed one-third of the slab thickness and conduits shall be placed not closer than three diameters on centers, except at cabinet locations where the slab thickness shall be increased as accepted by the Engineer.

Where conduits are indicated to be concealed in the bottom floor slab, they shall be placed in the concrete slab and not in the fill below the slab. conduits for lighting branch circuits may be placed in the structural concrete slab only where indicated.

12-9-12 OUTDOOR RACEWAY

Underground ducts and conduits shall be PVC direct burial type.

Underground conduits and ducts shall be installed in reinforced-concrete envelope for 1m from building wall penetrations, and shall be concrete encased under paved areas, and for 1m from the edge of paved areas.

Concrete shall be Class B, as specified under Concrete. Reinforcing shall be as required.

All conduits shall be at least 50cm below the finished grade, unless otherwise indicated on the drawings. Precast-concrete or plastic spacers shall be used for spacing of the conduits during construction. Conduits shall be firmly weighted or wired together and staked before the concrete is placed to prevent the floating of conduits. Stakes shall be outside of the concrete envelopes and shall be firmly tamped and evened. All side forms shall be suitably braced. Weights shall be removed and concrete added to restore the duct bank to proper condition before the concrete is set.

Conduits runs shall follow straight lines as far as possible. Where deviation is required because of interference or other reasons, bends of sufficient radius for proper installation of cable shall be used.

12-9-13 CUTTING, THREADING, AND CONNECTION

All field cuts in raceways shall be square, and cut ends shall be filed and shall have burrs removed. An insulating bushing shall be installed on each end of conduit or tubing, unless the connector is designed to prevent contact with the cut end. All connections shall be mechanically strong and tight, and made up properly with approved connectors. No running threads shall be permitted. Where the surface coating is damaged or removed by cutting or threading, it shall be restored to his original conditions.

Flexible metal conduit, fittings, and accessories shall be installed in accordance with the requirements of the National Electrical Code or equivalent. Flexible metal conduit shall be used only for connections to motors, or to other equipment subject to vibration or adjustment. Each connection shall contain at least one-quarter bend so that no vibration can be transmitted beyond the flexible connection. A visible bonding wire shall be provided across each flexible connection. The size of the bonding wire shall be in accordance with the National Electrical code but in no case smaller than 4 mm^2. All bonding wires larger than 6 mm^2 shall be stranded.

Flexible metal conduit shall be installed to be mechanically strong and watertight, and located to reduce the possibility of damage to the exterior coating. Approved connectors that screw into the flexible conduit shall be used, and gaskets provided where needed.

12-9-14 BENDS

All bends shall be carefully made to prevent distortion of the circular cross section. Field-made bends in conduit shall have an inside radius of not less than nine diameters. Where bends of less than nine diameters are necessary standard factory elbows shall be used, however, the conduit size chosen shall be such as to permit a cable-bending radius within the factory elbow of at least eight times the cable diameter. Bends in parallel runs shall be concentric. No conduit shall have more than two 90° bends or the equivalent thereof between pulling points.

12-9-15 CONDUIT CLEANING

All conduit shall be carefully cleaned before and after installation, all ends shall be reamed free of burs, and inside surfaces shall be free from all imperfections likely to injure the cable.

After cleaning, the ends of all conduit shall be protected with standard caps to prevent the entrance of water concrete, debris, or other foreign substance.

12-9-16 INSTALLATION OF BOXES

PVC boxes may only be installed in dry, concealed, accessible locations. They shall not be installed below grade, in outside concrete or masonry walls or in floor slabs subject to moisture. Sheet metal boxes shall not be used where vaportight fixtures are required, for surface mounting of wall switches and receptacles, or for any outdoor use.

Boxes shall be installed in conformity with all requirements of the National Electrical Code or equivalent. Boxes shall be designed for installation in the type of construction involved. All boxes shall be supported in the same manner as required for conduit. Boxes shall be sized to provide a bending radius for the wire, or cable, of at least eight times the diameter, or per the United States National Electrical Code, whichever is larger.

All outlets shall be centered in panels, or spaces provided therefore, and adjusted to the structural finish. Where specific locations are not indicated, the outlets shall be located with respect to the equipment served, and with the approval of the Engineer.

Cast-metal boxes with threaded conduit hubs shall be assembled in such a manner that the conduit connections and gasketed covers are watertight. All unused threaded openings shall be closed with pipe plugs and compound.

Ceiling fixtures shall be supported from a 10mm hickey in the outlet box. Where fixtures require more than one support point, the additional support shall be from a 10mm hickey separately installed for that purpose, or any type of box with a similar fixture stud in it.

Large boxes and cabinets shall be grounded with a separate ground cable connection between two ground lug on the box and the nearest ground bus. The ground connection shall have a current-carry capacity as required by the National Electrical Code or equivalent based upon the largest current-carrying circuit within the box.

12-9-17 MOTOR AND EQUIPMENT CONNECTIONS

At all motors and other electrically operated equipment to which conduit connections are required to be made, the contractor shall provide a complete connection between the end of conduit and the terminal box of the motor or other equipment.

Conduits installed in or extending up through floors shall be terminated in such locations as to permit a direct connection to the motors.

Connections shall be made with flexible metal conduit, as previously specified.

12-9-18 HAZARDOUS AREAS

Proper care shall be taken to ensure that all conduits, fittings, equipment and devices are installed in accordance with the requirements of the National Electrical Code for Hazardous Locations, Class 1, Division 1, Group D, or equivalent.

In such hazardous locations, conduits terminating at boxes enclosing circuit-opening equipment shall be sealed at the entrance to the enclosure with approved compound-filled, commercial, sealing fittings to prevent passage of explosive or combustible gases through the conduits.

All conduits leading from or entering such hazardous locations shall be similarly sealed at points of exit or entrance, and exposed conduits passing through hazardous locations shall also be sealed at both the entrance to and the exit from the hazardous locations.

Conduit connections shall have at least five threads tightly engaged, and made up with suitable thread compound.

Hazardous areas are so indicated on the drawings.

12-10 ELECTRIC WIRES AND CABLES

12-12-1 GENERAL

All wires and cables shall be in accordance with SASO and made by an acceptable manufacturer. Wires and cables installed without prior review shall be subject to removal at the Contractor's expense.

12-12-2 MATERIAL AND STRANDING

All conductors shall be of stranded copper. Material and stranding of conductors shall conform to BS, VDE or IEC Standards.

12-12-3 WIRE AND CABLE SIZES

Wire and cable sizes shall be as indicated on the drawings, however, in no case shall their size be smaller than required by the IEE regulations (UK), NEC, VDE or IEC.

Unless otherwise indicated, no lighting and power conductor shall be smaller than 2.5 mm^2.

Conductors for control shall be 1.5mm^2. Conductors for branch lighting circuits shall be of such sizes that the greatest voltage drop between the lighting panel and the center of load will not exceed 2% at rated load. Conductors for instrumentation shall be 1.5mm^2 minimum.

12-12-4 WIRE AND CABLE TYPES

Wires totally enclosed in conduits shall be PVC insulated, 84 °C, 450/750V, to BS 6004, or approved equal.

Wires and cables that run in methods other than mentioned above shall be PVC or XLPE insulated and PVC sheathed, 85 °C, 600/1000 V, to Bs 6346.

Instrumentation wiring shall be utilized where milliamp signals are to be transmitted. They shall be shielded multicore copper conductors, size 1.5mm^2. Conductors shall be individually insulated with polyvinyl chloride. Pairs shall be twisted with varying lay (if more than one pair) and covered with cable tape and a copper shielding tape. Jacket shall be polyvinyl chloride. Cables shall be rated 600 volts and 90 °C.

12-12-5 INSTALLATION

All wiring shall be installed in conduit unless otherwise indicated and shall be in accordance with the applicable provisions of the National Electrical Code and as indicated on the Drawings.

Conductors shall be continuous from outlet to outlet and no splices shall be made except within outlet or junction boxes.

All conductors to be contained within a single conduit shall be drawn at the same time.

A wire-pulling compound shall be applied to conductors being drawn through conduits.

A reasonable amount of slack shall be left in each conductor at panelboards, outlet boxes, and other devices to facilitate the making of joints and connections of fixtures and equipment.

No cable bend shall have a radius of less than eight times its diameter.

Underground direct burial installation of duct shall be as follows:

- Duct shall be laid on a 15 cm clean fine sand cushion, covered with another 15cm of similar sand, covered with concrete protective tiles or purpose made PVC protective tiles, backfilled and compacted every 15cm layer. Provide duct markers or cable markers flush with paving and protruding 2cm in unpaved areas, at every 30 meter run and at every change of direction.

- The PVC protective tiles shall have inscriptions of warning of existence of electrical cables. If concrete tiles are used, provide a terratape with similar warning, inscription just under the tiles.

12-12-6 CONDUCTOR IDENTIFICATION

Each wire shall be labeled at both termination points. Individual conductor or circuit identification shall be carried throughout, with circuit numbers or other identification clearly stamped on terminal boards.

In junction boxes, cabinets, and terminal boxes where the total number of control, indicating, and metering wires is three of fewer and no terminal board is provided, each wire, including all power wires, shall be properly identified by means of a plastic-coated, self-adhesive, wire marker.

In cases similar to the above where the terminal board are provided for the control, indicating, and metering wires, all wires including motor leads and other power wires too large for connection to the terminal boards shall be identified by wire markers as specified above.

12-12-7 CONNECTORS AND TERMINAL LUGS

For the wiring of circuits consisting of 6mm², 4mm² or 2.5mm² self-insulated pressure type connectors shall be utilized for all splices or joints.

All wires connected to terminal boards, terminal blocks, or to other similar terminals shall terminate by means of ring tongue, nylon self-insulated, tin-plated copper pressure terminals.

12-12-8 TERMINAL BOARDS

Terminal boards where indicated or required shall be of the fabricated type 600 volts screw terminals, with white marking strips for wire identification, they shall be of the 4-, 6-, 8-, or 12-pole type, as necessary.

Terminal strips shall be clearly and permanently marked with ink or indelible pencil. Each wire shall be marked consistently throughout the entire system, using wherever possible the notation of the wires given on the manufacturer's wiring diagrams.

12-12-9 MEDIUM TENSION CABLES 20 KV RATED (XLPE Insulated)

Conductor shall consist of plain, annealed electrolytic copper, circular standed in conformity with IEC 502.

Insulation shall consist of thermosetting XLPE material in conformity with IEC 502 and shall be flame retardant type.

The screening shall be a semi-conducting layer extruded or lapped, completely covering the insulated conductors, with a copper tape completely covering the semi-conducting layer as per IEC 502.

The assembly shall consist of laid up insulated and screened conductors, filled where necessary with non hygroscopic material with an extruded thickness of thermoplastic material.

Armouring for medium tension cables shall consist of two layers of steel tape, conforming to IEC 502.

The sheath shall consist of PVC or PE thermoplastic material conformity to IEC 502.

Tests shall be required as per IEC 502 for raw materials and on finished products and shall include:

a) **Cable High Voltage (Routine Tests)**

Each drum length or coil of completed cable shall be tested in accordance with the relevant IEC recommendation/BSS.

b) **Conductor Resistance (Routine Tests)**

The resistance of the conductors shall be measured in accordance with relevant IEC 228 recommendations/B.S.S 6360.

c) **Galvanising Test**

Samples from each 15 or part of 15 drum lengths of all steel wire armoured cables shall be subjected to galvanising tests in accordance with IEC recommendations B.S.S. 729.

d) **Insulation, Bedding and Sheath**

The insulation, bedding and sheath shall be tested in accordance with relevant IEC 304 recommendations/B.S.S. 6746 as the case may be.

e) **Meausrements of Thickness and Weights**

One metre length cable shall be cut from every 10 drums of finished cable, examined in detail and the following measurements and weights taken.

1. Thickness of insulation in mm
2. Thickness in mm of conductor insulating shield, and copper shielding tape where application.
3. Thickness of PVC sheath in mm.
4. Thickness of bedding in mm where applicable.
5. Number and thickness of armoure steel wire.
6. Thickness of PVC overall serving in mm.
7. Weight of copper conductors in gm.

f) **Accelerated Treeing Test**

Accelerated treeing test shall be carried out on a sample of XLPE cable by use of high frequency power heating to operating temperatures (90ºC or above) and introduction of liquids into the conductor and into a container surrounding the insulation shield.

12-11 WIRING DEVICES

12-11-1 GENERAL

The Contractor shall furnish and install all of the wiring devices as indicated on the drawings and as specified herein.

Wiring devices shall be surface or flush mounted depending upon conduit installation method in that room.

Both European and American types wiring devices shall be approved.

If American type is proposed minimum rating shall be 15 Amp.

12-11-2 WALL SWITCHES

Wall switches shall be AC general-use snap switches so constructed that they can be installed in flush or surface device boxes. Each switch shall be totally enclosed in a composition case, with an insulated mounting yoke, binding screw-type terminals satisfactory for the type of wire used. Switches shall be either single-pole, 2-pole, as indicated on the drawings, and shall be rated as indicated on the drawings at 250 volts minimum.

12-11-3 WEATHERPROOF SWITCHES

Weatherproof switches shall consist of acceptable switches as specified hereinbefore in gasketed cast metal boxes. The switch shall be operated through a shaft in cast metal cover.

12-11-4 RECEPTACLES

Receptacles shall be so constructed that they can be installed in flush or surface device boxes. Each receptacle shall be of the grounding type, with ampere rating as shown on the drawing, with a composition case, and an insulated mounting yoke, and side-wired, binding screw type terminals acceptable for the type of wire used.

Weatherproof receptacles shall consist of acceptable receptacles as specified herein before in gasketed cast metal boxes and shall be supplied with a cast metal cover.

12-11-5 SPECIAL SWITCHES

Explosion-proof receptacles shall be approved for the purpose and shall conform to NEC class I hazardous areas.

12-11-6 **DEVICE PLATES**

Device plates shall be suitable for the type of outlet boxes and enclosures used. Except as otherwise specified, device plates shall be made of high corrosion resistant, stainless steel not less than 0.75mm thick.

12-11-7 **GROUNDING**

All devices shall be grounded.

Switches and their metal plates shall be grounded through the switch mounting yoke, and grounding wire.

Receptacles and their metal plates shall be grounded through a positive ground connection to the outlet box and the grounding system. The ground to each receptacle shall be maintained by a spring-loaded grounding contact to the mounting screw, or by a grounding jumper, both grounding system at all times.

12-12 LIGHTING PANELBOARDS

12-12-1 GENERAL

Lighting Panelboards (LP) shall be factory assembled, dead front type, and shall have branch circuit breakers and a main circuit breaker or main lugs only, as indicated on the drawings.

Panelboard shall conform to NEMA Standard PB1, or equivalent.

Main and neutral buses shall be minimum 98% conductivity rectangular copper bars, provided with bolted-type lugs, as necessary.

Buses shall be drilled to fit either "A" or "B", or "C" connectors, and connectors shall be interchangeable.

Connectors shall be installed to provide distributed phase sequence.

Buses, connectors, and terminals shall be silver plated to a minimum thickness of 0.13mm.

All terminal lugs shall be prevented from turning per NEMA Standard PB1, and shall be suitable for the conductor material and size.

12-12-2 CIRCUIT BREAKERS

Branch and main circuit breakers shall be type plug-in type (Miniature type) and shall have trip settings, and number of poles, as indicated on the drawings. All circuit breakers shall have their ampere trip rating clearly marked and visible.

The circuit breakers shall have quick-make, quick-break, toggle mechanisms, and contain thermal-magnetic, inverse-time-limit overload and instantaneous short-circuit protection on all poles, unless otherwise indicated on the drawings. Automatic tripping shall be indicated by the breaker handle assuming a clearly distinctive position from the manual ON and OFF position. Breaker handles shall be trip-free on overloads.

The use of single-pole breakers with handle ties or bails in lieu of multipole breakers will not be permitted.

Branch and main circuit breakers shall have an interruption rating of not less than 10,000 amp, symmetrical, at rated voltage, unless bracing requirements are shown to be higher, in which case interrupting rating shall be at least equal to the indicated bracing.

12-12-3 **CABINETS**

Unless otherwise specified, panelboard cabinets shall be constructed of code-gage, galvanized, sheet steel and shall be equipped with gutters of ample size for the risers and outgoing circuits. The cabinets shall not exceed 200cm in height.

Cabinet fronts, trims, and surface-mounted boxes shall be finished in ANSI No. 61 light-gray enamel, over a rust-inhibitive primer. The fronts (exterior trims) shall be attached to the boxes or interior trims, by quarter-turn, indicating trim clamps. The cabinets shall be designed for flush or surface mounting as applicable.

Each door shall be hung on fully concealed hinges. Screws for front (exterior trim) clamps shall be inaccessible when the door is closed. There shall be no extensions beyond the front surface of the door. All lock and catch components shall be recessed. It shall be impossible to remove the front (exterior trim) without opening the door. Each door shall have a combination catch and lock.

A directory frame with transparent cover shall be furnished and installed on the inside of the door of each panelboard. The directories shall be type-written and shall indicate the location and purpose of the outlets and equipment supplied by each circuit.

12-12-4 **RATINGS**

Lighting panelboards shall be rated for 380 volt duty, with 10,000 amp. symmetrical short circuit bracing, unless otherwise indicated.

12-13 DISTRIBUTION PANELBOARDS

12-13-1 GENERAL

The contractor shall supply and install the distribution panelboards (DP,EDP) as per NEMA Standard PB1 as indicated on the panelboards schematics and as shown on the drawings.

Distribution panelboards shall be provided with voltmeters, ammeters and instrument transformers.

Distribution panelboards shall be equipped with thermal magnetic molded case circuit breakers of frame and trip ratings as shown on the drawings.

Panelboards bus structure and main breaker shall have current ratings as shown in the panelboards schematics.

Panelboards shall have 380 volt duty rating and shall have short circuit current interrupting capacity equal to or greater than the integrated equipment rating shown on the drawings.

Short circuit tests on the overcurrent devices and on the panelboard structure shall be made simultaneously by underwriters laboratories UL 67 method of testing.

Panelboards circuit numbering shall be such that, starting at the top, odd numbers shall be used in sequence down the left-hand side and even numbers shall be used in sequence down the right- hand side.

Panelboards and protective devices shall be manufactured by General Electric (U.S.A), Catler Hammer (U.S.A.), Square D (USA) and Merlin Gerin (FRANCE), or approved euqal.

12-13-2 CABINETS AND FRONTS

Panelboard assembly shall be enclosed in a steel cabinet the rigidity and gauge of steel to be as specified in UL Standard 50 for cabinets. Cabinet shall be of sufficient size to provide a minimum gutter space of 10 cm on all sides. The thickness of the sheet steel shall be minimum 1.5 mm.

Fronts shall include doors and have flush, brushed stainless steel cylinder tumbler - type locks with catches and spring loaded door pulls. The flush lock shall not protrude beyond the front of the adjustable indicating trim clamps which shall be completely concealed when the doors are closed. Fronts shall have approved directories with name of panel, number of phases, wires and voltage written on them. Doors shall be mounted by completely concealed steel hinges. Fronts shall not be removable with door in the locked position. A circuit directory card shall provide a space of at least 0.5 cm high x 7 cm long or equivalent for each circuit.

The directory shall be typed to identify the load fed by each circuit.

Fronts shall be of code guage, gull finished steel with rust- inhibiting primer and baked enamel finish. Color shall be gray to ANSI No. 61, or approved equal.

Joints shall be welded, galvanized and reinforced where necessary and galvanized after fabrication.

12-13-3 **PANELBOARD BUS ASSEMBLY**

Bus for connections to the branch circuit breakers shall be the "Distributed Phase" or "Phase Sequence" Type.

Three-phase, four-wire bussing shall be such that any three adjacent single-pole breakers are individually connected to each of the three different phases in such a manner that two or three pole breakers can be installed at any location. All current carrying parts of the bus assembly shall be plated.

Main and neutral buses shall be minimum 98% conductivity rectangular copper bars, provided with bolted-type lugs as necessary.

Buses shall be rigidly supported and insulated and be so designed that branch circuits can be removed without disturbing adjacent units or changed without additional machining, drilling or tapping.

Necessary bussing, drilling and blank plates shall be provided for installation of future circuits when so indicated in the Schedules on the Drawings.

All screws and bolts used for making copper connections shall be equipped with lock washers. Riverted connections will not be acceptable.

Mains shall be equipped with solderless pressure indent type connectors and have means to prevent swiveling of connector.

Neutral busbars shall be full size and shall incorporate one neutral terminal for each single pole and neutral way.

Aluminium shall not be used for any interior panelboard parts.

Back pan or mounting on which buses and branches are mounted shall be rigid to properly support the component parts.

Reinforcing of back pan shall be by flanging or addition of angle iron.

Buses, connectors, and terminals shall be silver plated to a minimum thickness of 0.1 mm.

12-13-4 **GROUNDING**

An acceptable terminal bar for equipment grounding conductors shall be provided with a minimum number of cable terminations equal to the single pole number of ways of the panelboard.

Cabinet shall be provided with a ground connector welded to it.

12-13-5 **MOLDED CASE CIRCUIT BREAKERS**

Bolt-on molded case circuit breakers shall have trip settings, and number of poles, as indicated on the Drawings. All circuit breakers shall have their ampere trip rating clearly marked and visible.

Breakers shall have quick-make, quick-break, toggle mechanisms; and shall provide positive trip-free operation on abnormal overloads. Stationary and movable contacts shall be adequately protected with effective and rapid arc interruption. Each pole of the breaker shall be equipped with an inverse time delay thermal overcurrent trip element and magnetic instantaneous overcurrent trip elements for common tripping of all poles for multiple breakers. Multiple pole breakers shall have a single handle mechanism. Automatic tripping shall be indicated by the breaker handle assuming a clearly distinctive position from the manual ON and OFF position.

Circuit breakers shall have minimum RMS symmetrical interrupting capacities equal to the values indicated below for molded case circuit breakers unless otherwise indicated, and shall in no case be less than the busbar short circuit bracing of the panelboard:

Frame Size	: 250 A and below	800 A and above
Interrupting KA at 380 V	: 35 KA	42 KA

Each circuit breaker assembly shall have undergone and passed heat tests according to UL test procedures and shall be UL listed.

12-14 LIGHTING SYSTEM

12-14-1 GENERAL

The Contractor shall furnish and install complete lighting systems as indicated on the drawings.

12-14-2 LIGHTING FIXTURES

The types of fixtures shall be as tabulated on the lighting fixtures schedule. The Contractor shall submit for review all necessary data to shown that the fixtures he proposes to supply are of the same type, construction, and quality as those indicated.

Fixtures shall be furnished complete with lamps of the wattage's indicated.

12-14-3 LAMPS

Unless otherwise specified, incandescent lamps shall be standard, inside frosted, 220-volt lamps.

Fluorescent lamps shall be 36 watt cool white, with 3250 lumens and 18 watt with 1450 lumens minimum outputs.

12-14-4 BALLAST'S

Ballasts for fluorescent lamps shall be of the high power factor type. Ballasts shall operate one, two, or three lamps as required by the fixture.

Ballasts shall be quick start will be connected to system voltage, 220 volts as indicated. They shall be designed for operation at an ambient temperature of 50 ℃.

12-14-5 AUXILIARY LIGHTING UNITS

Each auxiliary lighting unit shall be a low-voltage (6 or 12 volts) type, self contained, and to UL or other approved standard.

12-14-6 INSTALLATION OF LIGHTING FIXTURES

Installation of fixtures shall comply with the applicable provisions of the United States National Electrical Code or other approved standards. Pendant fixtures shall be suspended by means of suitable outlet-box cover-type aligners, each having a flexible joint permitting the unit to hang plumb. Stems shall be 1.25cm galvanized-steel conduits, unless otherwise specified.

Vapor tight aligners shall be used with vapor tight fixtures.

12-15 MISCELLANEOUS EQUIPMENT

12-15-1 GENERAL

The Contractor shall supply and install the following equipment as shown on the Drawings, and as herein specified.

12-15-2 DISCONNECTING SWITCHES

Switches shall be non-fusible single throw, number of poles and rating as shown on the Drawings.

Switches shall be quick-make, quick-break type, capable of making, carrying and interrupting specified current at its rated voltage.

Switches rated more than 200 amps when used with motors shall be plainly marked "Do Not Operate Under Load".

Switches rated 200 amps or less, when used with motors shall be motor circuit switch type, of horse-power rating equal to, or more than, that of the associated motor and having interrupting capacity at least equal to the maximum operating overload current of the motor at rated voltage.

Motor circuit switches shall incorporate all necessary auxiliary contacts to isolate auxiliary power supplied (if any) associated with the starter.

Isolating switches with no interrupting ratings shall not be used, for any type and rating of motor.

Enclosures shall be treated with a rust-inhibiting phosphate, and finished in grey baked enamel.

12-16 MOTORS & STARTERS

12-16-1 GENERAL

The Contractor shall supply and install the motors and the starters under other sections when so mentioned, as shown on the Drawings and as herein specified.

Motor starting method and corresponding furnished starter shall be concordant.

12-16-2 RATING OF MOTORS

Motors shall be suitable for operation on 220 volt single phase or 380 volt 3-phase, 3-wire, 60Hz system and shall be dripproof fan cool induction motor type unless otherwise indicated or specified.

All motors shall have a service factor of 1.15. Motors of ratings smaller than 1 HP shall be single phase and those of ratings 1 HP and larger shall be three phase, unless otherwise indicated or approved.

Every motor shall be of sufficient capacity to operate the driven equipment under all load and operating conditions without exceeding its rated name-plate current or power or its specified temperature limit. The horsepower ratings for motors shown on the Drawings must be considered as an indication only. For the use of motors other than that specified, the Contractor shall assume the cost of, and responsibility for satisfactorily accomplishing all changes (including engineering costs of redesign by the Engineer) in the work as indicated and specified. All derating resulting from site conditions shall be allowed for in the design.

12-16-3 TYPES OF MOTORS

All motors shall be of a type approved for starting characteristics and ruggedness as may be required under the actual conditions of operation.

All motors shall have class F insulation as a minimum requirement.

The motors shall be designed so that the maximum temperature rise at continuous run under full load and operation conditions shall be in accordance with NEMA Standards for Motors and Generators and based on the local ambient temperature.

12-16-4 **GENERAL DESIGN OF MOTORS**

Motor windings shall be braced to withstand successfully the stresses resulting from the method of starting. The windings shall be treated thoroughly with approved insulating compound suitable for protection against moisture and slightly acid or alkaline conditions.

Bearings shall be of the self-lubricating type, designed to ensure proper alignment of rotor and shaft, and to prevent leakage of lubricant.

Bearings for open motors shall be of the sleeve or ball type, as specified under respective items of mechanical equipment.

Indoor motors located in relatively clean surrounding, free from any abrasive or conducting dust or chemical fumes, shall be enclosed ventilated dripproof type. Otherwise motors shall be totally enclosed fan cooled type.

Vertical motors if any shall be provided with thrust bearings adequate for all thrusts to which they can be subjected in operation.

Vertical motors of open type shall be provided with drip hoods of approved shape and construction. When the drip hood is too heavy to be easily removed, provision shall be made for access for testing.

12-16-5 **MOTOR TERMINAL BOXES AND LEADS**

Motors shall be furnished with oversize conduit terminal boxes to provide for making and housing the connections and with flexible leads of sufficient length to extend for a distance of not less than 10 cm beyond the face of the box. The size of cable terminals and conduit terminal box holes shall be as approved by the Engineer. An approved type of solderless lug shall be supplied. Totally enclosed motors shall have cast iron terminal boxes.

12-16-6 **MOTOR SHOP TESTS**

Motor shop tests shall be made in accordance with IEEE Test Code as specified in the ANSI C50 for Rotating Electrical Machinery or approved equal. NEMA Report-of test forms shall be used in submitting test data.

Complete tests of each motor supplied shall be made and certified shop test data sheets shall be submitted, unless witness shop tests are required by the Detail Specifications pertaining to the equipment. Each motor shall be tested for efficiency and power factor at 50, 75 and 100% of its rated horsepower, for temperature rise, torque, starting current and dielectric strength; and for compliance with all specified performance requirements.

12-16-7 **MOTOR STARTERS**

Motor Starters shall be built and sized in accordance with NEMA Industrial Control Standards, ICS-1970 or IEC 947 or approved equal. Starters shall be non-reversing, magnetic type unless otherwise indicated or specified.

Contactors shall have their contact easily accessible for inspection and maintenance.

It shall not be possible to remove the arc-quenching chamber when the contactor is energised.

The arc-quenching chamber shall be fully enclosed in order to prevent the escape of hot gases.

It shall be impossible to operate the main and auxiliary contacts manually by means of the position indicator.

Auxiliary switches shall be equipped with fail-safe linkage in order to exclude false signals.

The rated withstand voltage shall be 600 V and the test voltage shall be 3000 V for 1 minutes (IEC 9471).

The insulation class coil shall be "B" according to VDE 0660.

All starters shall comply with coordination type 2 per IEC 947-4-1 when installed in motor control center (MCC).

All starters shall be provided with thermal cutout devices in each phase calibrated for close protection of the motors against overloads. These devices shall trip the starters in case of overload and shall not allow it to be reset except manually. The thermal overload relays shall be adjustable from 90 to 110% of nominal rating. A single calibration adjusts all three legs. The overload relay shall be ambient compensated.

All motors 15 HP and larger shall have their starters equipped with integrated multiple function solid state motor protection for:

- Thermal overload
- Assymetry/ phase failure
- High overload/stalling

Motor starters larger than 15 hp. and motors for operation under fire shall also have earth fault protection integrated within the solid state motor protection unit.

THE STARTER SHALL BE PROVIDED WITH AUXILIARY CONTACTS FOR THE CONNECTION OF SIGNALING, INTERLOCKING AND OTHER CIRCUITS AS REQUIRED FOR THE CONTROLS.(AT LEAST 2 NO. + 2 C).

Unless otherwise indicated, all starters shall be provided with START-STOP pushbuttons, and RED & GREEN pilot lights, all located on the starter front cover. An overload reset button shall be provided inside the cover. Pushbuttons shall be momentary contact or maintained type as applicable to the function of control.

Starters shall have horsepower ratings at least equal to ratings of motors they serve.

Voltage of control circuit shall not exceed 220 volts.

Starters shall be electrically held in, providing inherent undervoltage release.

Starters when not part of a motor control center and are located indoors shall be encased in a NEMA 1 gasketed dust-proof enclosure, unless otherwise indicated.

"Star-delta" starters if any shall have additional "Star" and "Delta" contactors which shall be electrically and mechanically interlocked to close the motor in "Delta" connection with the supply after the "Star" contactor has opened. A timing device shall be fitted to provide and adjust time in "Star" before changing over to the Delta connection.

"Star-Delta" Starters shall provide close transition.

Schematic wiring diagram of all starters shall be provided on the interior of starter front cover.

12-16-8 MOTOR CIRCUIT PROTECTIVE DEVICE

Motor circuit protective devices shall comply with IEC standards 957-1 and 957-2. Alternative proposals to ratings shown on drawings based on manufacturers recommendations shall be subject to the Engineer's Approval. The Contractor shall in any case be responsible to assure that the circuit protective devices shall carry the starting current with no tripping, and if reducing trip rating results in a reduction in frame size, the Contractor shall make sure that the new rating withstands the available short circuit current.

12-16-9 **SOLID-STATE REDUCED VOLTAGE MOTOR STARTER (SOFT STARTER)**

Solid state , soft starter shall be used where indicated on drawings and shall be quoted separately as an alternative to star-delta starter.

1. The solid-state reduced voltage motor controller shall consist of a power section, a one-piece printed circuit logic board and a field wiring interface terminal board.

2. The power section shall be three-phase, 60 Hz. and rated for the hp, current, and voltage as shown on the drawings. It shall consist of three sets of back-to-back phase controlled power semi-conductors. Maximum current limit shall be 500% for standard units.

3. Resistor/Capacitor snubber networks shall be used to prevent false firing of SCR'S due to dv/dt characteristics of the system.

4. Fan cooled units shall be supplied with thermal sensors on the heat sink to trip the control protective logic for over-temperature condition. Thermal sensors shall be rated 90 ºC maximum.

5. The one piece logic board shall be mounted for easy testing, service and replacement.

6. Three-phase current sensing via current transformers for closed loop control to insure motor stability shall be provided.

7. The logic board shall used quick disconnect plug-in connectors for current transformer inputs, line-and-load voltage inputs, SCR gate firing output circuits and status panel.

8. The logic circuitry shall include as a minimum:

   a. Short circuit electronic trip overcurrent protection. Time not to exceed ½ cycle.

   b. Inverse time running overcurrent protection.

   c. Auxiliary trip circuitry.

   d. Gate firing circuit lockout protection on trip.

   e. Fault relay lockout protection.

   f. 250%-500% current limit adjustment.

g. Minimum and maximum voltage adjustments.

h. Voltage stability adjustment.

9. The logic board soldering shall be treated with a conformal protective coating system.

10. The logic board shall include, as standard, current and motor slip sensing circuitry that continually monitor motor load and regulate motor voltage to minimize motor kWh energy consumption.

11. The solid-state logic shall provide phase sequence protection.

12. External interface circuitry shall include 220-volt relay logic interface capability.

13. Tripped functions shall be designed to be cleared by removing power from the solid-state logic board.

14. Controllers for motors larger than 200 hp shall have additional features as follows:

a. Dwell time at current limit with ramp continuation after acceleration.

b. Individual light emitting doides (LEDs) to indicate run, undervoltage, phase loss, phase current unbalance, overcurrent trip, overtemprature, current limit, end of ramp and incorrect phase rotation.

c. Single-phase protection with built-in short time delay.

d. Undervoltage protection with built-in short time delay.

e. The power section shall have metal oxide varistor (MOV) type surge suppressors across the SCRs rated 10% above the SCR rated voltage. The power semi-conductors shall be rated with peak inverse voltage at least 2.5 times SCR rated line-to-line voltage. Data shall be made available on tolerances to incoming line voltage surges or line spikes. Data shall include both magnitude and time content of each spike (volgage peaks and volt-seconds) plus tolerance to repetitive surges.

f. 100%-120% full load running current trip adjustment.

g. 200%-500% current limit adjustment.

15. Two ground lugs shall be furnished, one for incoming and one for outgoing ground connections.

16. Power terminations shall consist of pressure type terminals for top or bottom entrance.

17. Enclosure

    a. Enclosures shall not be less than 16-gauge steel. Type 12 enclosures shall be of welded construction with gasketed heat sink and doors.

    b. Doors shall include plastic device holders for mounting up to six (eight for above 200 hp motors) operator devices.

    c. External and internal steel surfaces to be painted shall be thoroughly cleaned and phosphatized prior to application of paint. They shall then be primed with a corrosion-resisting coating. Cabinet and door finish shall be manufacturer's standard.

    d. Controllers for motors above 200 hp shall include the following:

        1. The operating handle of the disconnect, when supplied, shall always remain connected to the breaker or switch. The operating handle shall not be mouted on the door of the enclosure, but on the controller for safe "stand-aside" operation. The position of the operating handle will indicate ON or OFF position of switch or circuit breaker and include provision for padlocking in the OFF position.

        2. Interlock provisions shall prevent unauthorized opening or closing of the starter door with the disconnect in the ON position.

        3. The structure, when floor-mounted, shall be provided with adequate lifting means and shall be capable of being rolled or lifted into installation position and bolted to the floor.

        4. A door-mounted status panel shall provide individual light emitting diodes (LEDs) to indicate run, undervoltage, phase overtemperature, current limit, end of ramp and incorrect phase rotation.

12-17 MOTOR CONTROL CENTER(S)

12-17-1 GENERAL

The Contractor shall supply and install the motor control center(s) as shown on the Drawings and as herein specified.

Motor control center shall consist of enclosed, cabinet type structure with components as specified hereinafter, free standing on channel front sills with sections bolted together to make up the center. Motor control center shall be NEMA Class II type C wiring unless otherwise indicated.

Motor control center shall have 600 V duty rating.

Outline dimensions of motor control center and arrangement of compartments shall be approximately as indicated on the Drawings or as per IEC Form 3a.

Enclosures for the motor control center shall be NEMA 3 gasketed unless otherwise indicated for use on 50 KA rms short circuit at 380 volts 3-phase, 4-wire, 60 Hz system up to 600 volts.

It shall consist of one or more enclosed vertical sections joined together to form a rigid free standing assembly. The construction of the motor control center shall meet the requirements set forth by Underwriters Laboratories Publication UL-845, NEMA Publication No. ICS-2-322 and the National Electrical Code.

Incoming power feeder shall be cable entering at the top or bottom as applicable and shall terminate on main lugs or main protective device in accordance with the Drawings.

Ample space shall be provided for system control and operation sequence devices, etc. specified under another section. These devices will be supplied, installed and wired in the motor control center by the mechanical contractor.

Motor control center shall be manufactured by General Electric (USA), Cutler Hammer (USA), Telemecanique (France) or approved equal.

12-17-2 VERTICAL SECTIONS

Vertical sections shall be totally enclosed, dead front and back reinforced, welded and bolted to be self supporting and free standing without need of covers and doors for alignment and rigidity. All bolted connections shall have lock washers or equivalent. The assembly shall include horizontal and vertical buses, wireways and units as herein specified. Each end shall be designed to readily allow future additions. All external welds shall be sanded smooth. Each vertical section shall be composed of fixed units.

12-17-3 **BUSES**

The top of each section shall contain three main horizontal copper busbars, which shall run, continuously through the motor control centre from section to section. Provisions shall be made for easy additions and connections to adjacent sections. The buses shall be braced for an RMS symmetrical short circuit current of the values shown on the Drawings.

Each section shall contain three vertical busbars running the full working heights of the section and connected to the horizontal main busbars.

Continuous current ratings of horizontal and vertical busbars shall be in accordance with temperature rise specifications set forth by UL, ANSI and NEMA Standards.

Wireway compartments for horizontal wiring shall be provided at the top and bottom of the control center. A vertical wiring compartment shall be designed so as to allow installation wiring to the units with the unit doors open but with the unit in place.

Grounding (earthing) bus shall be sized in accordance with the NEC, but shall not be less than 240 mm2 in cross-section. Grounding (earthing) bus shall extend through the entire length of the assembly.

Oversize holes shall not be used for bus connections. Holes shall not be more than 1.5 mm over the nominal diameter of the bolt. Slotted holes shall be kept to a minimum. No more than one slotted hole shall be used in a connection.

All bolted connections shall be capable of being tightened from the front, and shall be silver plated to a thickness of not less than 1.5 mm.

All bolted connections shall be fastened by lockwashers, locknuts, or equivalent. Heavy standard size flat washers shall be used on each side of the connection, unless other means of providing wide contact pressure area are used.

All bolts and related hardware shall be heavy plated cadmium or hot-dipped galvanized steel, or equal.

Isolation barriers shall be provided between the horizontal bus and front horizontal wireways

Barriers shall effectively protect the buses from contact with any object in, or falling from the wireways.

Vertical barriers shall be provided with readily removable solids, plates or plugs over stab contact openings to allow addition or rearrangement of units.

12-17-4 **UNIT COMPARTMENT**

Each unit compartment shall be provided with an individual front door. Starters and feeder-unit doors shall be interlocked mechanically with unit disconnect device to prevent unintentional opening of the door while energized and unintentional application of power while door is open. Means shall be provided for re-easing the interlock for intentional access to the interior at any time and intentional application of power if desired, while door is open. Padlocking arrangement shall permit locking the disconnect device with door close or open.

Components of each module shall have individual printed label identifying size, voltage, ampere rating, etc. Starter wiring diagram and overload thermal cutout device installation instruction shall be attached to each starter.

12-17-5 **UNIT COMPONENTS**

The starter units shall be of the combination type consisting of components as shown on the Drawings.

The motor horsepower indicated on the Drawings may not be the same as those supplied. If larger motors are supplied, components, cable and conduits of larger capacity may be necessary and if so they shall be provided.

Starter units shall be provided with 2 pilot lights for tripping and running conditions.

12-17-6 **MOTOR STARTERS**

Motor starters shall be furnished where indicated on the motor control center schedules.

Starters in the motor control center(s) shall be part of combination starters as shown on the Drawings.

When integrated within a motor control center starters of air handling units related to A/C chilled water system shall incorporate all the additional control devices that are described under Mechanical Specifications.

Starters shall be as otherwise specified under "MOTORS & STARTERS".

12-17-7 **BREAKERS**

Circuit breakers shall be thermal magnetic, molded case bolt-on type furnished where indicated on the Drawings. Breakers shall provide thermal inverse time-limit overload and fixed magnetic instantaneous instantaneous short-circuit protection and shall be as otherwise specified under "POWER & DISTRIBUTION PANELBOARDS".

Breakers shall be ambient compensated type with a built in compensator to carry rated load at 50C.

Circuit breakers shall have frame sizes with short circuit interrupting ratings at least equal to the short circuit bracing of the motor control center busbars.

12-17-8 **TERMINAL BLOCKS**

Terminal blocks shall be installed and internally connected by the manufacturer, for all internal and external wire number. Each terminal point shall have a large marking area or to be equipped with two marking areas.

In addition, with each group of terminals per unit, a minimum of 20% unconnected extra non-load terminals, but not less than one, shall be provided for the Contractor's external connections.

12-17-9 **CURRENT, POTENTIAL & CONTROL POWER TRANSFORMERS**

Current, potential and control powertransformers shall be installed as indicated on the Drawings or as needed. They shall be designed for 600 volt service. They shall have adequate thermal capacity and mechanical strength to match the short circuit capacity of the motor control center.

Potential transformers primaries and secondaries shall be protected by fuses. Primary fuses shall be current limiting.

12-17-10 **INSTRUMENTS**

Instruments such as ammeters, voltmeters, etc. shall be approximately 9 cm square, semiflush mounted, and shall be accurate within one percent of full scale. Scale shall be 250^{o} and selected so that normal voltage or full-load current shall indicate at approximately 70% of scale reading.

Test blocks and plugs for testing all instruments and instrument transformers shall be provided.

10.17-11 **SELECTOR SWITCHES**

Selector switches for use in instrument and control circuits shall be of the rotary type with a rectangular escutcheon. The operating handle shall be of the round knurled or notched type for voltage and current.

12-17-12 **FINISH**

All steel, other than some interior components which are made corrosion resistant by galvanizing or plating shall be thoroughly cleaned, treated with rust inhibiting primer and baked enamel finished with an approved color to ANSI 49.

12-17-13 **NAMEPLATES AND INDICATING LAMPS**

Nameplates shall be provided on and in the motor control center as specified below. All nameplates shall be fastened in place with corrosion-resistant screws.

The top wiring space and each unit door shall be provided with laminated plastic nameplate engraved white on black in English and Arabic.

All starters control wiring schematic diagrams shall be provided at the back of the unit doors.

Manufacturer's nameplate on the front of the control center shall be provided. Manufacturer's identification on each drawout unit shall also be provided.

Indicating lamps shall be provided as required.

12-17-14 **WIRING AND INTERCONNECTIONS**

Full inter-section wiring for complete control system shall be provided.

12-17-15 **MISCELLANEOUS**

Devices such as Hand-Off-Auto selector switches, automatic electric alternator, etc. shall be provided as specified under other sections.

If the motor control center is for the chilled water pumps, it shall incorporate the following items:

- Operation selector switch, three position: Manual-Off-Auto. On "manual", the pumps shall be possible to be operated individually out of the system control. On "off", no pump shall be possible to be operated. On "Auto" all duty pumps shall operate in the System when system "ON" pushbutton is pressed.

- Standby/duty selector switch, with number of positions at least equal to the number of pumps. This switch shall select the standby pump (or duty pump in case of 2 pumps only).

- System "Start-Stop" pushbutton.

- Space for sequence controller as described under "General" of this subsection.

12-17-16 **SPARE PARTS**

All necessary spare fuses for control circuits and control transformers shall be provided.

12-18 ELECTRICAL CONTROLS AND MISCELLANEOUS ELECTRICAL EQUIPMENT

12-18-1 GENERAL

The Contractor shall furnish, install and connect the electrical control equipment and miscellaneous electrical equipment, including such instruments and devices as are indicated on the drawings and as herein specified. Enclosures for electrical equipment shall be as indicated on the drawings.

Where type of enclosure is not indicated or specified, the equipment shall have a NEMA type 12 enclosure.

The Contractor shall furnish and install all steel channels necessary for mounting of electrical equipment.

12-18-2 WIRING OF MISCELLANEOUS INSTRUMENTS AND DEVICES

The Contractor shall make all electrical connections required for recording and indicating instruments and miscellaneous devices and shall provide electrical supplies to the metering, instrumentation, control, and alarm systems.

The Contractor shall furnish, install, and connect Hand-Off-Auto switches, safety switches, tumbler switches, and other accessory devices as indicated on the drawings or necessary for the control or motors and other electrical equipment or devices.

12-18-3 PUSH-BUTTON STATIONS FOR MOTOR CONTROL

Push-button stations shall be furnished and installed as shown on the drawings at the motors. All push-button stations shall be designed for heavy-duty service and shall provide momentary contacts or maintaining contacts, as indicated on the drawings or as necessary for starting and stopping the motor.

Where control equipment is not within sight of the motor, a safety lockout station with position indication shall be located near the motor to prevent application of current.

Where indicated, push-button stations shall be provided with nameplates mounted on or above the push-button stations in an acceptable manner. Nameplates shall have white letters, on a black background. A sample nameplate shall be submitted for review.

NEMA Type 4 watertight push-button stations shall have stainless steel enclosures.

12-18-4 **OUTSIDE ALARM HORNS**

Outside alarm horns shall be weatherproof, adjustable, vibrating diaphragm type with cast-metal box and grille capable of producing 103 decibels at 3m.

12-18-5 **TIMER**

Timers shall have an outer scale for the "Off" time and an inner scale for the "On" time. Each time scale shall have a knot actuated set point for setting the exact On-Off timer required. Accuracy shall be 1/2 of dial span. Contact ratings shall be a minimum of 10 amp. at 220 volts AC resistive load. The timer shall have a dial range of 30 hours and a minimum setting of 1/2hr. The timer shall automatically reset itself after each cycle.

12-18-6 **LEVEL ELECTRODES ULTRASONIC CONDUCTIVITY LEVEL SYSTEM**

The contractors shall supply level electrodes suitable for the application with the following specification:

- **Durable Construction**

  reliable on/off liquid level control for alarms and pump control and suitable for sewage waters and most conductive liquids

- **High, low or latching level control**

- **Weatherproof to IP56**

- **Two sets of DPDT contacts**

  - Duplicate contacts for direct control and visual alarm.

Noflote Electrodes:

A complete Noflote system comprises one or more **Sensing Electrodes** an **Noflote Controller** containing switching circuitry and control relays, either in chassis-only form for cabinet mounting (multipoint applications), or in a die-cast aluminum, IP56, weatherproof case.

A **Noflote system** detects the electrical resistance between a Noflote **electrode** and an **earth electrode.** The earth reference connected to the controller may be the walls of a metal vessel, pipe work within the vessel, the earth rod of a multiple sensor or another Noflote electrode.

When the liquid rises to touch the Noflote electrode an internal relay energizes (or de-energizes) to operate an alarm, pump etc. Complex processes can be controlled automatically by means of two or more noflote systems.

Double Trip:

Comprises two single trip controllers in one housing, each of which operates independently of the other in conjunction with its own Noflote sensing electrode. Each control channel has one control relay with two sets of changeover contacts.

Noflote Electrodes:

Noflote level systems require an earthing electrode extending below the lowest Noflote sensing electrode. In many cases this earth is provided by pipe work, a rising main or the largest electrode of a multiple type sensor. Where there is no convenient earthing electrode, an additional Noflote electrode, longer than the longest sensing electrode, must be installed.

Light Electrode:

Comprises a die-cast aluminium alloy head with mild steel or stainless steel boss and a stainless steel electrode rod.

Operating temperature limits

-10^{o} to $+55^{o}$ C

Operating humidity limits

0 to 80%

Power supply

240V and 380V nom., 50/60 Hz.

Relay contact rating

Double pole changeover contacts.

Safety on failure

Fail-safe at high or low level is set by link on printed circuit board.

Response time

5s or 0.5s (by on-site removal of capacitor).

Cable run

Maximum length between electrode and controller – 300 m (975 ft)., dependent on immersion resistance range and cable used.

Housing

Die-cast aluminium alloy, weatherproof case with screw on gasketed cover, finished in dark gray epoxy resin based paint.

Protection

IP56

Chassis housing

ABS plastic dust cover with terminals top and bottom. No internally mounted signal lamps, Protection IP20, Dimensions 128 mm (5.0 in.) high x 128 mm (5.0 in.) wide x 85 mm (3.35 in.) deep.

Weight

2.2kg (4.84 Ib) in die-cast case,
1.0 kg (2.2 Ib) chassis only.

81 NEO and 81 NEW Electrodes:

Insulation resistance:
20 MΩ min.

Insulant materials:
Acetal and rigid polythene.

Insulant tube length:

81 NEO	25 mm (0.98 in.)
81 NEW	760 mm (29.92 in.)

Electrode Tube:

Standard ¾ in. (27 mm) o.d. galvanized gas pipe or stainless steel. Customer normally supplies electrode tube to fit the electrode head. Tube must be plugged at bottom end in type 81 NEW. Mild steel or stainless steel tune can be supplied on request [200 mm (7.87 in.) minimum, 4500 mm (177.1 in.) maximum in 100 mm (3.93 in.) steps}

Electrode Head:

Manufactured in cast-iron, conical shape, fastened by four stainless steel screws. A Langite gasket is used for the waterproof type.

Range of adjustment within the head:

120 mm (4.72 in.)

Minimum rod length below lower face of mounting face:

200 mm (7.87 in.)

Mounting:

65 mm (2.56 in.) steel flange (160 mm o.d.) (6.3 in.) to BS4504 Table 6/8 with 60 mm (2.36 in.) clearance hole.

Protection:

81 NEO	IP56
81 NEW	IP66

Weight (without tube):

81 NEO	5.5kg (13.75 lb)
81 NEW	6kg (13.2 lb)

Rod length:

100 mm (3.93 in.) to 2500 mm in 20 mm (0.78 in.) steps earth rod on type 81 NEM is 60 mm (2.36 in.) longer than lower rod.

Electrode head:

Die-cast aluminium alloy with threaded cover, waterproof with silicone rubber ‘O’ ring.

Range of adjustment within head:

None

Mounting:

Type 81 NEL Stainless steel boss screwed ½ in. BSP with nut and washer

Type 81 NEW Stainless steel boss screwed 1¼ in. BSP with nut and washer or mild steel mounting bracket.

Maximum working pressure:

Type 81 NEL	10 bar at 20° C (145 psi at 68° F)
Type 81 NEW	6 bar at 20° C (87 psi at 68° F)

Electrical connection:

Threaded for 20 mm conduit entry.

Protection:

IP56.

Weight:

Type 81 NEL	0.7kg (1.54 lb) – 500 mm rod length.
Type 81 NEW	0.8kg (1.76 lb) – with 3 rods approx.500mm long.

12-19 EARTHING SYSTEM

12-19-1 GENERAL

A) Description Of Work

Complete installations to earth every source of energy and to provide protective earthing and equipotential bonding, based on the TN-S system arrangement, including:

main earthing terminals or bars
exposed conductive parts of electrical equipment
extraneous conductive parts

B) Regulations And Standards

Carry out work in accordance with the following:

IEC publications 364-3 and 364-4-41 Electrical Installations in Buildings

latest edition if IEEE Regulations for Electrical Installations in Buildings - London.

C) Equipment Data

Prior to ordering materials, submit data for approval including, but not limited to, manufacturer´s catalogues for earth rods, connecting clamps, earthing conductors, protective conductors, bonding conductors, connectors and other accessories, exothermic welding kits and tools etc., and samples of conductors as requested.

D) Shop And Construction Drawings

Submit drawings for approval including, but not limited to, the following:

1. exact location of earth pits, rods and details of installation and connections.

2. exact routing of buried earthing conductors with indication of cross-section, depth of laying and covering.

3. cross sectional area of all earthing, protective and bonding conductors.

4. layout and details of earthing provisions at substations, generator rooms, swit, distribution panelboards etc., indicating fittings used, insulation, plates and marking, passage and routing of earthing conductors, conduit, sleeves, grooves, niches etc., giving sizes and dimensions of component parts.

12-19-2 **PRODUCTS AND SYSTEM**

A **Earthing System (Type Tn-S)**

i) **General Requirements**

ii) **Component Parts** of earthing system are to include the following:

- earth electrode (rods, tapes etc.)
- main earthing terminals or bars
- earthing conductors
- protective conductors
- equipotential bonding conductors
- accessories and termination fittings, bonding, welding kits and other materials.

iii) **Earth Electrodes:** is to consist of one or more earth rods, interconnected by buried earthing tape or cable, which is to have a total combined resistance value, during any season of the year and before interconnection to other earthed systems or earthing means, ***not*** exceeding 5 ohms. Distance between two rods is not to be less than the length of one rod, or 3 m minimum.

iv) **Alternative Earth Electrode:** other types of earth electrode may be used, after approval, including:

- cast iron pipes with special surround material
- copper plate(s)
- tape mats (strips)

vii) **Supplementary Equipotential Bonding:** all extraneous conductive parts of the building such as metallic water pipes, drain pipes, other service pipes and ducting, metallic conduit and raceways, cable trays and cable armour are to be connected to nearest earthing terminals by equipotential bonding conductors. Cross-section of protective bonding conductor is not to be less than half that of the protective conductor connected to respective earthing terminal, and minimum 4 mm2.

viii) **Main Equipotential Bonding:** main incoming and outgoing water pipes and any other metallic service pipes are to be connected by main equipotential bonding conductors to main earth terminal or bar. Bonding connections are to be as short as practicable between point of entry/exit of services and main earthing bar. Cross-sections of conductors are not to be less than half that of the earthing conductor connected thereto, and minimum 6 mm2.

ix) **Identification:** connection of every earthing conductor to earthing electrode and every bonding conductor to extraneous conducting parts is to be labelled in accordance with the Regulations, as follows:

"SAFETY ELECTRICAL CONNECTION - DO NOT REMOVE".

x) **Identification:** protective and earthing conductors are to be identified by combination of green-and-yellow colours of insulation or by painting bar conductors with these colours, as approved.

12-19-3 TRANSFORMER SUBSTATION EARTHING

MV SWITCHGEAR is to have separate main earthing bar connected to framework or earth bar of each item by bare conductor and the earth-electrode by two insulated earthing conductors, one at each end of bar, via testing joints. Earthing conductor is to be minimum 50 mm².

LV SWITCHGEAR is to have separate main earthing bar connected to framework or earth bar of each item by bare conductor and the earth electrode at two extreme ends by two insulated earthing conductors through testing joints. Earthing conductor size is to be minimum 120 mm².

TRANSFORMER EARTHING TERMINAL is to be connected to LV main earthing bar by bare copper earthing conductor not less than 20 mm² per 100 kVA of transformer rating, with a minimum of 35 mm².

TRANSFORMER NEUTRAL (STAR POINT) is to be connected by insulated earthing conductor (colour black) to LV side main earthing bar. Neutral earthing conductor is to be sized for maximum earth fault current for 5 seconds with final conductor temperature not exceeding 160 deg. C or sized not less than 30 mm² per 100 kVA of transformer rating, and with a minimum of 50 mm². Where a neutral is directly connected to earth electrode, an insulated disconnecting device is to be provided at the transformer.

LIGHTNING ARRESTERS are to be directly connected to earth electrode, following the shortest path. Each lightning arrester is to be connected at a dedicated earth rod.

12-19-4 EARTHING OF MAIN DISTRIBUTION BOARDS, MOTOR CONTROL CENTERS

MAIN EARTHING BAR is to be provided in main distribution board or motor control center and connected to earth electrode by two insulated conductors via testing joints.

12-19-5 **GENERATOR PLANT EARTHING**

GENERATOR NEUTRAL (STAR POINT) is to be connected by insulated earthing conductor through the neutral earthing link or device to main earthing bar. Neutral earthing conductor is to be suitably sized to carry maximum earth fault current for time it takes the system protection to operate with final conductor temperature not exceeding 160 deg. C, but not less than 30 mm² per 100 kVA of generator rating, with a minimum of 50 mm².

GENERATOR EARTHING TERMINAL is to be connected to main earthing bar by bare copper conductor of cross section not less than 20 mm² per 100 kVA of generator size, with a minimum of 35 mm².

SWITCHGEAR (ATS) AND CONTROL GEAR: earthing terminals or bars of switchgear and control gear are to be connected by separate protective conductors to respective normal and emergency main distribution board earth bars.

EXTRANEOUS CONDUCTIVE PARTS including steel frames, battery racks, day-tank, pumps and piping are to be connected by bare copper earthing conductors to main earth bar in compliance with bonding regulations.

12-19-6 **MECHANICAL PLANT ROOMS AND FIXED MACHINERY**

MAIN EARTHING BAR OR LOOP is to be conveniently located in mechanical plant rooms, and connected by earthing conductors to exposed conductive parts of motor control centre at its earthing bar, and to motors, switches and other electrical equipment etc. at their earthing terminals, using 20 x 2 mm bare copper strips or 35 mm² bare copper conductor (minimum size) or as required to carry maximum earth fault current for 1 second with final conductor temperature not exceeding 200 deg. C.

MAIN EARTHING BAR OR LOOP is to be connected at two extremely separate points to earth electrode, directly through two test joints by insulated earthing conductors, or connected to main earth bar by protective conductors.

MOTOR AND OTHER EQUIPMENT EARTH TERMINALS are to be connected also by protective earth conductors of each branch circuit to earth terminal/bar at motor control centre, panel or distribution unit.

12-19-7 **MATERIALS AND PRODUCTS**

EARTH ROD: copper steel, 14 mm diameter, 2.5 m length, extendible as necessary to obtain required earth resistance. Earth rod is to be complete with couplings, head and bolted connector of sufficient size, and number of bolted clamps to connall cables terminated thereto.

TAPE MATS: where earth rods are not likely to be used, earth electrode is to consist of parallel and perpendicular copper strip, 2.4 m apart, welded together by exothermic welds to form a grid. Tape is to be 25 x 2.5 mm strip conductor.

EARTH PIT: precast, square or circular section concrete handhole (minimum 450 mm internal diameter), with concrete cover, and extending to about 150 mm below top of earth rod. Earth pit is to be provided for each earth rod where connected to an earthing conductor. Cover is to have inset brass plate with inscription ´Earth Pit - Do Not Remove´.

EARTHING CONDUCTORS: insulated or bare copper conductor as described in the Specification for the particular application.

TESTING JOINTS (TEST LINKS): copper or copper alloy, with bolted end connections, disconnectable by use of tool, and suitably sized for earthing conductors or earth bar connection. Links are to be fixed to porcelain or other approved insulating supports. Contact surfaces are to be tinned.

PROTECTIVE CONDUCTORS: single core stranded annealed copper, PVC insulated cables, having rated insulation grade compatible with circuit protected, or to be a conductor forming part of a multi-core cable, colour coded.

MAIN EARTHING BAR: hard drawn copper, 40 x 4 mm where formed into a closed loop, and 50 x 6 mm where open ended. Earth bar is to be labelled ´Main Earth Bar´ and is to be drilled, for connection of conductors, at a spacing not less than 75 mm, and is to be supplied with copper alloy bolts, nuts and washers and wall mounting insulators.

PROTECTIVE BONDING CONDUCTORS: bare copper strip conductors, annealed stranded copper cable or flexible strap.

EARTHING ACCESSORIES: copper or copper alloy, purpose made, of approved design, compatible with points of connection, and of adequate cross-section and current carrying capacity. Connectors and clamps are to be bolted type. Bolts, nuts and washers are to be high quality phosphor bronze or copper silicon alloys.

12-19-8 **FIELD AND INSTALLATION WORK (INSTALLATION)**

Continuity: ensure that complete earthing system is electrically continuous and mechanically secure.

Earth Rods: while siting earth rods, ensure that resistance areas associated with individual rods do not overlap. Earth rods are to be located at a distance greater than 600 mm from foundations of buildings. Where rock is encountered, a hole of sufficient size is to be drilled before lowering the rod. Conductive filler such as Marconite or Bentonite or equal filler that will not corrode, is to be provided around the rod.

Buried Earthing Conductors are to be laid at a depth not less than 0.8 m from

Earthing Conductors are to follow shortest path between earth rods and main earthing terminals or bars, and are to run in PVC conduit (duct) fastened to building structure by approved supports and extending 0.2 m above level, and are to be protected against mechanical damage and corrosion.

Protective Conductors: separate protective conductors, which are not part of a cable, are to be fixed on same support or drawn into same conduit as circuit conductors.

12-19-9 **TESTS ON SITE AND RECORDS**

A) Combined Resistance of earth electrodes is to be measured during dry season and checked against specified resistance.

B) Electrical Continuity of all earthing and protective conductors including main and supplementary equipotential bonding conductors is to be checked.

C) Records: submit the following:

1. scaled drawings, as-installed, showing actual layout and specification of all components of earthing system.

2. nature of soil and any special earth arrangements etc.

3. date and particulars of soil conditioning method and agents if used.

4. test conditions and results obtained.

12-20 LIGHTNING PROTECTION SYSTEM

12-20-1 GENERAL

The Contractor shall supply and install a complete system of lightning protection as shown on the Drawings based on Faraday cage, as here in specified and in compliance with the provisions of the latest "code for Protection against lightning" as adopted by the NFPA and "Underwriter" Laboratories Inc. The system shall installed by an experienced firm specializing in this type of work. The system shall include air terminals, main and secondary conductors, fasteners, metal bonds, splicers, earthing and all necessary parts to install a complete lightning system.

12-20-2 MATERIALS

Materials shall comply in weight, size and composition with the requirements of Underwriters, Laboratories Inc. and the NFPA Code relating to this type of structure.

12-20-3 AIR TERMINATIONS AND DOWN CONDUCTORS

Air terminations shall be 5/8" in diameter, 60cm long, 98% conductivity copper and pointed taper and shall extend not less than 25 cm above the object they protect, and shall have a proper base support for the surface on which they are used and shall be securely anchored to this surface.

Air terminals shall be provided along parapet of roofs at different levels of roof floors available.

The mounting of air terminals shall be indicated on shop drawings to be submitted by Contractor.

Horizontal and down conductors shall be of 70 mm2 bare stranded copper conductors or approved alternative material. Strand cross section shall not be less than 2 mm2. Conductors shall be run down to pits with minimum number of bends. Bends shall be of large radius (minimum 20 cm). Bends less than 20 cm radius shall be supported at two points not more than 7.5 cm on each side from the centre line of the bend. Conductors shall be coursed to provide a two-way path to ground. Conductors shall be run down as far as possible from any structural or other metal bodies.

12-20-4 FASTENERS

Fasteners shall be spaced not more than 1 m apart on all conductors. Nails, screws, or bolts employed to secure the fasteners shall be of the same material as the fasteners. Galvanized or plated steel nails, or bolts are not acceptable.

Masonry anchors shall have a diameter of not less than 0.6 cm and shall be set with care. Holes to receive the shank of the fastener or fitting shall be of correct size, made with proper tools and preferably made in the stones rather than in the mortar joints, when set the fit shall be tight against moisture and capable of withstanding a pull test of 40 kg.

12-20-5 **INTERCONNECTION OF METALS**

All ungrounded sizeable metallic objects within 60 cm of the system or metal connected to the system shall be bonded to the lightning grid with approved fittings and conductor. Connections between dissimilar metals shall be made with approved bimetallic connectors.

12-20-6 **SPLICERS**

Bronze pressure type cable splicers shall be provided where necessary at intersection of main and branch conductors. Splicers shall be furnished complete with required bolts and washers. Cables shall be clamped so as to get maximum strength.

12-20-7 **EARTHING TERMINALS**

Each down conductor shall terminate in an accessible earthing pit, as shown on the Drawings. The rod shall be a deep driven earthing rod (3 m minimum total length), or where necessary, drilling of ground, insertion of rod and backfilling with soil conditioning agents such as Bentonite or Marconite.

Clamps connecting down conductors to earth rods shall make contact with the earth rod for a distance of 4 cm measured parallel to the axis of the ground rod and with the cable itself for a distance of at least 4 cm. Clamps shall be secured with at least two bolts or cap screws.

The resistance of the individual earthing pits shall not exceed 10 ohms. The diameter of ground rod shall not be less than 1.5 cm.

Earth connections shall be of copper covered electrodes and shall be driven to a minimum depth of 3 meters to reach permanent moisture.

Earth Termination network: earth electrodes are to be interconnected and buried with the top at least 1 m below ground surface and minimum 0.6 m from the foundations. Combined resistance to earth of whole network is not to exceed 5 ohms.

Common Earthing: earth termination rods are to be interconnected in a ring around the structure and bonded to earth electrode of protective earthing system, forming a common earth ring of total resistance value to earth below the lower value of any of the two systems.

Joints and Interconnections in earth termination network are to be exothermic welds except that down conductor is to be connected by a single or multi-conductor bolted U-connector clamp.

The necessary common grounds shall be provided between the lightning protection system and electric grounds, and underground metallic piping systems, conduits etc. where more than one source is used.

12-20-8 **INSTALLATION**

The installation shall be made in an inconspicuous manner. Conductor shall be coursed within 60cm of outer edge of flat roof. All materials shall be fastened to eliminate any possibility of displacement and subsequent maintenance. Lightning system shall be manufactured by Furse (England) Thompson (USA), Independent Protection Company Inc. (USA) or approved equal.

12-20-9 **LIGHTNING & OVERVOLTAGE PROTECTION SYSTEM**

A. General

Furnish and install a complete lightning & overvoltage arresters. Class B Lightning arresters shall be installed at the main distribution switchboard. Class C overvoltage arresters shall be installed at the distribution panelboard.

B. Material Description

1- Lightning current arresters

Lightning current arresters should be of Class B with the following specifications:

Continuous operating voltage	250V AC 50 Hz
Tested to	E DIN VDE 0675 part 6
Lightning impulse current	75 KA / pole; 100 KA/2 poles or more
Voltage protection level	< 3.5 KV
Response time	< 100ns

Only class B lightning current arresters with gliding spark gap technology shall be accepted. Varistors based class B shall not be approved.

2- Overvoltage arresters

a) Class C arresters should be with the following specifications:

Continuous operating voltage	250V AC 50 Hz
Tested to	E DIN VDE 0675 part 6
Nominal discharge current	15 KA
Maximum discharge current	40 KA
Response time	<25ns

Class C overvoltage arresters shall be using varistor technology with thermal disconnector that disconnect in case of damage.

Class B and Class C arresters shall be installed according to manufacturer recommendation in order to provide energy coordination.

C. Data Network Protection

Data network (Token ring, Ethernet, 10 base T, 100 Base TX, Coaxial Ethernet, RS 485, RS232, RS422, IBM Twinax, and ISDN primary multiplex terminals), telephone lines, low voltage control lines, PLC shall be protected by suitable protectors as per manufacturer recommendation.

12-21 CONTROL AND INSTRUMENTATION

12-21-1 General

The contractor shall supply and install all the required field measuring devices, sensors and main control panel equipped with all necessary switches, pushbuttons, indicating lights, instrument indicators, recorders and annunciator panel.

Also the contractor shall supply and install personal computer system which can display plant-wide data, operating displays, diagnostic, alarm messages which aid in monitoring the operation condition and status of each plant unit as well as generate the required forms of reports. The computer shall consist of CPU (Central Processing Unit) and combine a CRT, keyboard and printer.

The system shall be suitable for installation and operating under the environmental conditions of the plant, which is mainly hot, dusty and humid weather.

The main control panel and the personal computer shall be designed to accommodate all the requirements of the first , second and third stages of the project. Instrument cutouts shall be made on the main control panel for future instruments on the second stage of the project. The instrument cutout shall be covered with suitable blank panel.

The instruments shall be in a minimum number of standardized designs. All the instruments sand equipments shall be from the manufacture's latest and proven design.

12-21-2 Design of Equipment

A. All instrumentation, including application, selection and installation, shall conform to the best standard industrial practice and the ISA Recommended Practices and Standards.

Instrumentation symbols and identification of functions for detailed design shall be based on ISA or Din standards.

Specifications for instruments and control equipment shall include ISA or other data sheet forms and be submitted to the Engineer for approval.

Instruments shall be manufacturer's standard type and use standard ranges where possible.

All instrument loops shall be designed "fail safe".

Solid-state electronic instruments shall be utilized in control room and field device transmission.

Electrical signals shall be 4 to 20 ma from a 24 VDC power supply.

All electrical instruments except recorders, which are part of a control, alarm, indicating or shutdown loop, shall be powered from the facility UPS (Uninterruptible Power System).

B. Panel Mounted Instruments

1) General

Panel mounted instruments shall be the miniature, pullout type mounted in trays.

All arcing contracts shall be hermetically sealed and all plug-in electrical connectors shall be gold plate.

Electronic instruments shall not be affected by FM or AM type communication transmitter / receivers operated within 30.48 cm (12 inches) of the instruments.

Electronic instruments shall be solid state type devices.

Accessible span and zero adjustments shall be provide on all measuring elements.

Instruments shall maintain performance characteristics through temperatures ranging from 0^{o} C to 50^{o} C.

Charts or scales shall be evenly divided, direct reading type, or shall have powers of 10 multipliers.

2. Controllers

Controllers shall be the full view indicating type having an adjustable set point, manual control and an automatic-manual transfer switch.

Controllers shall have provisions for displaying the process, output and set point values.

Controller automatic-manual transfer switch shall be designed for bumpless switching from the manual to automatic mode or vice versa.

Controllers shall be provided with a direct or reverse output selector.
Controllers shall have proportional automatic-reset control modes. Each mode of control shall be individually adjustable.

Anti-reset wind-up provisions shall be included on all controllers.

Controller set point accuracy shall be 0.50% of span.

Ratio Controllers shall be provided with a means to manually control the set point.

3. Recorders

Strip chart recorders shall be 15.24 cm (6 inches) wide (double width) type.

Chart drives shall be synchronous electric motor drives with a chart speed of 1.9 or 2.54 cm per hour (3/4 or 1 inch per hour).

Recorder shall be furnished with safety interlock switches that disconnect power from the chart drive when the instrument is removed from the housing.

Each recorder shall be furnished with two years' supply of chart rolls and ink.

Recorder accuracy shall be +/- 0.5% of full scale.

4. Indicators

Indicators shall be the vertical scale type.
Indicators shall have 1.5% accuracy.

5. Instrument Mounting Trays

Instruments shall be mounted in shelves.

Each instrument shall have a cord set terminating on the rear of the shelf. The cord set shall be long enough to remove the instrument from the front of the panel.

C. Pressure Measuring Instruments

Pressure measuring elements may be bourbon tube, spiral, helical, bellows or diaphragm type depending upon the service.

Over-range protection shall be provided for pressure actuated instruments, pilots, gauges, etc., that may be subjected to pressures that could damage the calibration of the instrument.

Pressure actuated instruments, pilots, gauges, etc., in pulsating services shall be equipped with pulsation dampeners.

All pressure gauges shall have stainless steel bourbon tubes, movements, micrometer pointers and forged steel sockets with wrench flats. Where corrosive conditions are present, special consideration should be given to the selection of proper gauge material. Pressure gauge dials shall be 114.3 mm (4-1/2 inch) diameter. Pressure switches shall have a setting accuracy of +/- 2 percent of range.

D. Transmitter

Transmitter total error shall be +/- 0.5 percent of span.

Electronic Transmitters shall be all solid state.

Zero and span adjustments shall be the mechanical type.

Electronic transmitters shall utilize a tow wire system for signal and power.

A field mounted millimeter meter shall be provided for each electronic transmitter.

The ambient temperature effect on zero shift shall not exceed +/- 2.5 % of span per 55^{o} C (100^{o} F) temperature change.

Zero Shift shall be less than 0.1 percent of span for a 10 percent change in supply voltage.

E. Field Mounted Switch Devices

Switches shall be hermetically sealed and snap acting.

Switches shall be direct operated type.

Set points shall be field adjustable unless specified otherwise.

12-21-3 **Computer System**

The computer system is designed as a dual system, shall be located in the main control room and shall combine the following:

Hardware: CPU (Central Processing Unit), colour monitor (CRT), Keyboard, Printer and plant interface.

Software: System configuration vendor standard & user application displays, report generation.

The plant software system shall be complete with a date base and VDU display structure to accommodate the ultimate capacity of the plant.

The main function of each computer is to monitor, record, provide and display the plant information such as flow rate indications, flow quantities (Totalization), Alarms, Reports Dynamic Plant-graphic displays, ……etc. as a computerized assistance to the computers as specified is primarily VDU based. The following provides a brief summary of the technical and functional requirements of the system.

Central Processing Unit (CPU)

The computers shall be based don the Inter "Pentium" micro-processor and equipped with the following:

PCI local bus

64 bit graphics accelerator card

256 kb secondary cache

256 Mb RAM (up gradable)

40 GB Hard Disk

PCI and ISA expansion slots

The CPU shall accept flow rate signals 4-20 mA DC, discrete inputs, perform the configured functions and produce the required reports.

The CPU shall include programs to perform the following functions:

1. Real-time executive.
2. Calculations (add, subtract, multiply, and divide).
3. Totalization of flows.
4. Alarm checking.
5. Generate reports on demand or automatically at regular times.

System Data Base:

The database to be entered into the database can be as follows:

- Real time data like current flow rates, values derived from totalization etc.

- Static data like alarm message, VDU display formats, logging formats etc.

- Historical data with describe the past performance of the plant over defined intervals of time in form logs / reports.

The Engineer will advice on the classes of Logs / Reports (Daily log, Weekly long,

Monthly log) which they require.

Colour Monitor

A 17", high resolution, table mounted colour monitor with real-time plant graphic displays shall be provided. The display shall have minimum SVGA resolution.

The following controls shall be provided on the front panel of the monitor:

- Power on / off switch.
- Brightness.
- Contracts.

The monitor shall be fitted with an automatic degaussing facility to minimize error introduced by an external magnetic field.

The cathode ray display tube in the monitor shall be equipped with suitable safety shield for the protection of personnel.

The monitor shall be micro-processor-based and capable of producing the plant overview graphic, operating displays, ….etc. The graphic displays shall be interactive with process in that it allows real-time display of flow rates, alarms adjacent to the appropriate graphic symbols.

The display hierarchy shall be structured so as to allow the operator to see more detail at successive levels and to move freely between displays. The operator shall be able to call up any display through adequate index pages.

Display-building function shall be provided to enable modifying and deleting existing displays and easily build interactive new displays without resorting to programming languages.

The display facilities available on the monitor shall be as follows:

- Alphabetic characters, numeric characters.
- Graphic symbols such as lines and realistic representation of plant equipment like valves, pumps, aeration tanks, clarifiers screw pump etc.
- Flashing each character.

Alarm list shall be a summary of all alarms that have occurred in the plant over defined time period. Each alarm shall be shown in the following format:

- Time occurred.
- Tag number.
- Alarm message.
- Time acknowledge.

- Time cleared.

It shall be possible to change the description text for any alarm via monitor without additional programming.

The alarm list shall be printed out on demand or automatically at regular intervals in chronological order.

Alphanumeric keyboard

The key board shall have same characters and layout as an ASCII "QWERTY" style keyboard. The keyboard shall contain standard alphanumeric character set (A-Z an 0-9), standard punctuation characters and other associated keys, including SHIFT, SPACE, BACK SPACE AND CAPS LOCK. Also special key shall be provided to facilitate cursor selection, system status and program editing.

The keyboard shall contain special editing keys, which aid in report building, display building,…etc.

The monitor shall have appropriate selection facility on the keyboard for display mode and amendment mode.

LED"s shall of provided for direct visual indication with regard to operational status of the keyboard an active operation mode of certain keys. The keyboard shall be portable type.

Printer

The printer is a data output device, which shall provide a hard copy of alarm logs, messages and required forms of reports. The printer shall be a block & white printer, bi-directional, microprocessor-based, medium speed, matrix print head and tabletop model. The printer shall be with black fabric ribbon.

Failure of the printer shall be automatically annunciated. Adequate amount of stationery shall be supplied with the printer.

The printer shall provide a full character set and shall operate at a speed not less than 60 characters per second. The carriage shall accommodate at least the same number of characters as the number characters on one line of a VDU display. The printer shall be capable of operation in the powered up state of 24 hours per day and 7 days per week. Provision shall be made, if necessary, to reduce the noise level during print operation.

The printer shall satisfy the following:

- Be turned on and off under processor control and run only when required for printing.

- Accept inter fold paper and produce up to one carbon copy if required (The Engineer will advice), one fold of the paper shall accommodate 1 VDU page.

- Provide status indications including paper supply status locally and to the processor.

- Provide full character sets in both English and Arabic languages (The Engineer will advice).

General Software Structure:

The General consideration shall be satisfied by the following requirements:

Modularity

The entire system software programmes, data tables, files shall be modular with clearly defined interfaces between modules such that changes in one module shall require only minimal changes in other modules.

Programmes and Data Tables

The software shall be organized such that data transfers between programmes shall be achieved by means of database so that logic changes in programmes do not interact.

Software Operation Medication

By manipulating data files and data tables only, it shall be possible to carry out the system medication for instance, ADD / Modify VDU display formats, change variables logged,…..etc.

Software Development

Facilities shall be included in the system for creation of new software aliments and shall be supported by file editing, file manipulation…..etc.

Documentation

The contractor shall supply complete documentation of all software included in this job, sufficient o allow appropriate trained Client personnel of to diagnose and rectify and malfunction whatsoever that might occur within the software and to implement additions o and extension of the software as may be required.

12-22 ELECTROMAGNETIC FLOWMETERS

12-22-1 DESCRIPTION

A. Work Included: Furnish, install, connect and test magnetic flowmeters in accordance with data sheets and as described herein.

12-22-2 APPLICABLE CODES AND STANDARDS

A. The following codes and standards are intended to provide an acceptable level of quality for materials and products. The Contractor may propose alternative codes and standards provided they give an equivalent degree of quality as the referenced codes and standards and are submitted for Royal Commission review and approval in advance of their use.

1. IEC - International Electrotechnical Commission:

2. IEC 144, I.E.C., Recommendation Degrees of protection of enclosures for low voltage switchgear and control gear.

3. B.S.I., British Standards Institution.

4. B.S. 5792, Electromagnetic Flowmeters.

12-22-3 SUBMITTALS

A. The following requirements are to be submitted for review by WASA:

1. Outline dimensions.
2. Connection diagrams.
3. Completed data sheets.
4. Completed data.
5. Operating manual.
6. Manufacturer's test certificate

12-22-4 PRODUCT STORAGE AND HANDLING

A. Provide each flowmeter with an identification mark and test certificate number thereon.

Ship each unit securely wrapped with silica get, dry wrap, packaged and labeled for safe handling in ship and to avoid damage or distortion.

Store flowmeter in a secure and dry storage facility.

12-22-5 **PRODUCTS**

All goods and products shall be procured, when available, from an in-Kingdom manufacturer. Procurement of all goods and products covered by these specifications shall be approved by WASA.

12-22-6 **DESIGN AND CONSTRUCTION**

A. **General:**

1. The meters covered in this specification operate on electromagnetic induction principles, and give output signals directly proportional to the rate of flow.

2. The measurement shall not be affected by stratified flow or any changes in electrical conductivity down to 20 micro-siemens.

3. Accuracy shall be within 1% of the maximum flow over the specified range.

4. Other performance requirements shall be as stated in BS5792.

B. **Primary Flow Element**:

1. Each element shall have a stainless steel metering tube and non-conductive liner suitable for the fluid being metered. End connections shall be flanged according to the relevant piping code.

2. The pickup electrodes shall be removable for cleaning or replacement without interruption of the flow.

3. Provision shall be made for late addition of ultrasonic cleaning of electrodes without structural changes being necessary.

4. Lifting lugs shall be provided for all meters 37 mm diameter and greater.

5. When fitted in lined, non-metallic or internally coated pipework, the meter shall be supplied with stainless steel grounding rings complete with grounding straps for connection to the meter body.

6. The primary flow element shall be constructed so as to withstand accidental flooding. The housing shall be to IEC 141 with minimum standard IP 68.

C. **Signal Converter**:

1. The power supply will be nominal 220V 60 Hz.

2. Analog output signal shall be 4-20 ma D.C.

3. A continuously adjustable pulse output shall be provided, capable of scaling to Engineering units, range 0-10 Hz, pulse width 50 ms or as specified.

4. Measuring ranges shall be continuously adjustable from 1-10 m/s with automatic facility for change-over to low range from 0.5 to 5.0 m/s for high accuracy measurement of low flows.

5. An adjustable low flow cut-out to avoid registration of spurious flows during flow system shutdown shall be provided.

6. The system shall be suitable for use with a portable calibrator unit for complete electrical checkout.

7. The enclosure shall be to IEC 144, standard IP 65 or better.

8. Continuously adjustable zero point controls shall be provided.

D. Pressure Test: Prior to calibration a hydraulic pressure test shall be performed at a pressure of at least 1.5 times the maximum design pressure.

E. Calibration: Meters shall be calibrated on cold water at the manufacturers plant or an approved testing facility. Calibration data shall be provided at time of shipment.

12-22-7 **EXECUTION**

A. Care shall be taken in handling the meter. Lifting lugs shall be used and great care used to avoid damaging the liner.

B. Flange bolts shall be tightened evenly and moderately to avoid liner damage.

C. The piping shall be arranged to ensure that the meter is always full of liquid.

D. Flowmeters installed in a vertical pipeline shall have upwards flow direction.

E. Meters installed in horizontal lines shall have electrodes located in the horizontal plane to ensure that trapped air cannot act as an electrode insulator.

F. There shall be a minimum of five pipe diameters of straight pipe upstream of the plane of the electrodes and two pipe diameters downstream.

G. The meter shall be located upstream of any flow or pressure regulating devices.

H. Means shall be provided to stop flow in the meter to enable zero checks to be made.

I. Careful attention must be paid to proper grounding of primary flow elements, since the metered liquid and the primary metering device should be at the same potential. Grounding rings shall be used in cases where the pipeline is coated internally or made of insulating material.

J. Particular attention shall be paid to flowmeters installed in systems that have cathodic protection. Insulating flanges and copper straps shall be used as appropriate.

12-23 ELECTRIC VALVE ACTUATOR

12-23-1 GENERAL

The actuator shall consist of a three phase electric motor, worm gear reduction, absolute position encoder, electronic torque sensor, reversing motor contactor, electronic control, protection and monitoring package, manual override handwheel, valve interface bushing, 32 character LCD, and local control switches all contained in an enclosure that is sealed to NEMA 4, 4X, 6, IP68, and (XP as required). Actuator design life shall be one million drive sleeve turns.

The power transmission shall be completely bearing supported, and consist of a hardened alloy steel worm and bronze alloy worm gear, oil-bath lubricated using a synthetic oil designed specifically for extreme pressure gear transmission service.

The motor shall be single phase/ 60 cycle/(230 volt) or 3 phase/60 cycle/(380 volt) with Class F insulation, and a thermister embedded within the motor windings to prevent damage due to overload. The motor shall be easily removed through the use of a plug-in connector and shaft coupling.

Valve position shall be sensed by a 15 bit, optical, absolute position encoder. Open and closed positions shall be stored in permanent, non-volatile memory. The encoder shall measure valve position at all times, including both motor and handwheel operation, with or without three phase power present, and without the use of a battery.

An electronic torque sensor shall be included. The torque limit may be adjusted from 40-100% of rating in 1% increments. The motor shall be de-energised if the torque limit is exceeded. A boost function shall be included to prevent torque trip during initial valve unseating, and a "Jammed Valve" protection feature, with automatic retry sequence, shall be incorporated to de-energise the motor if no movement occurs.

The control module shall include power and logic circuit boards, control transformer, and protection fuses, all mounted to a steel plate and attached in the control compartment with captive screws. The module shall be easily removed through the use of plug-in connectors. The module shall also include a reversing contactor, local control switches, 32 character LCD, and LED indicators. All internal wiring shall be flame resistant, rated 105^0C and UL listed.

The reversing contactor shall be mechanically interlocked to prevent simultaneous energising of the open & close coils. The control module shall also include an auto reversal delay to inhibit high current surges caused by rapid motor reversals. The control transformer shall include vacuum impregnated coils and dual primary fuses. A phase correction circuit shall be included to correct motor rotation faults caused by incorrect site wiring. The phase correction circuit shall also detect the loss of a phase and disable operation to prevent motor damage.

Remote control may be configured as 2, 3, or 4 wires for open-stop-close control. Terminals must also be provided for ESD (Emergency Shutdown) and Inhibit movement commands. The ESD signal shall override any existing signal (except LOCAL, STOP and INHIBIT) and send the valve to its configured emergency position. The ESD may be configured to override LOCAL, STOP, and/or INHIBIT.

Remote control functions may be powered by external 24Vdc, 125 Vac or the actuators internal supply of 110 VAC or 24 VDC. The internal supplies shall be protected against overcurrent and short circuit faults.

Terminals shall be included to connect the electronic control package, including display, to a back-up 24 VDC power source.

A dedicated circuit to prevent undesired valve operation in the event of an internal circuit fault or erratic command signal shall be included. An open or short circuit in the internal circuit board logic shall not energise the motor contactor, nor shall a single fused control relay contact fail to de-energise the motor contactor. The command inputs shall be optically coupled and requires a pulse width of at least 250 ms to 350 ms to turn on or off. In the event of an internal circuit fault an alarm shall be signalled by tripping the Monitor Relay and through LCD indication.

A padlockable LOCAL-STOP-REMOTE switch and an OPEN-CLOSE switch shall be included for local valve actuator control. The control switches shall not penetrate the controls cover and shall be designed to electrically isolate the actuator internal components from the external environment. The OPEN-CLOSE switch may be configured for maintained or push-to-run (inching) control.

Four latched contacts shall be provide for remote indication of valve position, configured as 1- N/O and 1-N/C for both the open and closed positions. The contacts may be configured to represent any other actuator status; mid-travel position, switched to local, over torque, motor over temperature, manual operation, switched to remote, switched to stop, valve moving, close torque switch, open torque switch, hardware failure, ESD active, inhibit active, or valve jammed.

A monitor relay shall be included and shall trip when the actuator is not available for remote operation. Both N/O and N/C contacts shall be included, rated 250VAC/30VDC, 5 amps. The yellow LED shall blink when the monitor relay is active.

A 32 character, Liquid Crystal Display (LCD) shall be included, to display valve position as a percent of open, 0-100%, and current actuator status. “STATUS OK” shall be displayed for an operable actuator. If the actuator is not operable, the appropriate alarm shall be displayed. The alarm shall be continuously displayed until the actuator is operable. Red, green, and yellow LED’s shall be included for open, close, stopped, and moving indication.

All calibration shall be possible without removing any covers and without the use of any special tools. All calibration shall be performed by answering the "YES" and "NO" questions displayed on the LCD. "YES" is signalled by using the OPEN switch and "NO" by using the CLOSE switch, as indicated adjacent to the switches. A configurable password option shall be available to prevent unauthorised changes.

All customer connections shall be located in a terminal chamber that is separately sealed from all other actuator components. Site wiring shall not expose actuator components to the environment. The internal sealing within the terminal chamber is suitable for NEMA 4,6, and IP68. The chamber shall include screw type terminals, 3 power and 50 control, for site connections. Three conduit entries, available as: (2) - 1.25" NPT (M32) and (1)-1.5" NPT (M40) shall be located in the terminal chamber.

The actuator shall be coated with a high solids epoxy E-coat primer and then finish coated with a polyurethane powder coat. The coating system shall be suitable for an ASTM B117 salt spray test of 1500 hours. External fasteners shall be high strength carbon steel, zinc plated, chromate hexavalent coated, and then top coated with a high strength, high endurance polymer. The fasteners shall be suitable for an ASTM B117 salt spray test of 500 hours.

A handwheel and declutch lever shall be provided for manual operation. The handwheel shall not rotate during electric operation nor can a seized motor prevent manual operation. Changing from motor to manual operation is accomplished by engaging the declutch lever. Energising the motor shall return the actuator to motor operation. The declutch lever is padlockable in the motor position.

The actuator shall include a removable bushing to mate with valve shaft.

Diagnostic facilities shall be included to accumulate and report the performance of the motor, encoder, contactor, cycle time, handwheel operations, actuator ID and output turns. In addition a torque profile of the reference baseline valve stroke and the last valve stroke shall be included. All diagnostic information shall be displayed on the LCD.

Every actuator shall be factory tested to verify: rated output torque, output speed, handwheel operation, local control, control power supply, valve jammed function, all customer inputs and outputs, motor current, motor thermistor, LCD and LED operation, direction of rotation, microprocessor checks, and position sensor checks. A report confirming successful completion of testing shall be included with the actuator.

All actuator designs shall have been tested to demonstrate electromagnetic compatibility with the following:

Emissions - Conducted and radiated emissions per CFR47 and EN 55011 and EN 50081-1 & 2.

Immunity - Electrostatic discharge (ESD) per IEC 801-2, Level 4 and EN 50082-1 & 2. Susceptibility to field immersion per IEC 801-3, Level 3, Electromagnetic field requirements EN 50082-1 & 2.

Electrical fast transients - IEC 801-4, Level 3 and Level 4 and EN 50082-2 for transients.

Surge immunity - IEC 801-5 Levels 1-4, EN 50082-2, and ANSI/IEEE C62.41

Mains AC (power) harmonic distortion - MIL-STD-462, method CS01.

Vibration and seismic capability shall be in accordance with MIL-STD-167, IEEE-344-1975, and IEC68-2-6. The actuator shall be tagged with CE mark per compliance with directives 89/336/EEC and 89/392/EEC.

12-23-2 **OPTIONS**

a) Analogue Position Transmitter (APT)

A non-contacting, internally powered, electrically isolated position transmitter shall be included to provide a 4-20 MA signal that is proportional to valve position.

b) Analogue Torque Transmitter (ATT)

A non-contacting, internally powered, electrically isolated torque transmitter shall be included to provide a 4-20 MA signal that is proportional to rated output torque.

c) Medtronic Option

A controller that alters valve position in proportion to a 4-20 MA analogue command signal shall be included. Positioning shall be accomplished by comparing the command signal to an internal position feedback. The internal feedback shall be of the non-contacting type. An automatic pulsing feature to prevent overshoot at the set point shall be included. Proportional band, deadband, signal polarity, motion inhibit time and fail position shall be adjustable through the LCD.

d) Alarm Relays

Two additional N/O and one N/C non-latching output contacts, rated 125 VAC, 5 amps and configurable to represent any actuator status: valve position, over torque, switched to local, switched to remote, switched to stop, handwheel operation, motor over temperature, open torque switch, close torque switch, hardware failure, ESD active, valve moving shall be included.

e) 2-Speed Timer

A 2-speed timer that permits the motor to be pulsed to achieve a longer stroking time shall be included. The pulsing mode may be configured for the open and/or close direction, for any portion of valve stroke with the ON pulse cycles configurable from .5-20 seconds and the OFF pulse cycles configurable from 1-200 seconds.

12-23-3 **DDC**

A digital communication control system that provides the ability to control and monitor up to 250 actuators over a single twisted pair cable shall be included. The communication network shall employ Modbus (Bitbus) protocol on an RS-485 network, and shall be redundant such that any single break or short in the communication cable shall not disable any actuators. Each actuator shall include an addressable field unit that communicates over the twisted pair network and executes open, close, stop, ESD, and GO TO position commands. The field unit shall also communicate all actuator status and alarm diagnostic messages over the same communication network.

12-24 PROGRAMMABLE LOGIC CONTROLLER

12-24-1 SCOPE

This specifications defines the minimum requirements for the Programmable Logic Controller (PLC). The PLC shall have a redundant CPU with Dual Modular Redundant (DMR) Architecture. The PLC I/O modules shall be Simplex and operated from the same CPUs mentioned above. All material used in the construction shall be selected for a long operating life in industrial/process applications.

Installation, operation and maintenance literature complete with detail arrangement drawings, dimensions, wiring diagrams, list of replacement parts and components specifications shall be supplied. Deficiencies in documentation provided by the Vendor shall be promptly corrected within two weeks upon written notice. The Vendor shall have sole responsibility for all documentation regardless of the original source of the hardware or software.

12-24-2 STANDARDS

The materials, design and construction of the PLC shall confirm to this specification and the listed applicable standards and codes unless stated otherwise in the purchase order. A clear and concise statement of compliance for each item shall be provided. Any deviations shall be itemized and included in the vendor's proposal.

Industry Codes and Standards:

ANSI/NFPA 70	National Electric Code (NEC)
ANSI/IEEE 488	Standard Digital Interface for Programmable Instrumentation
IEEE Std. C37.90.1	Surge Withstand Capability (SWC) Tests for Protective Relays and Relay Systems
IEEE-Std. C37.1	IEEE Standard Definition, Specification and Analysis of Systems used for Supervisory Control, Data Acquisition and Automatic Control
IEC 1131 Part1	Programmable Controllers Programming Languages
IEC 1131 Part 3	Programmable Controllers - Programming Language
IEC 801-3	Radiated Electromagnetic Field Requirements
IEC 801-4	Electrical Fast Transient/Burst Requirements
EIA/RS-232 C/E	Interface Between Data Terminal Equipment and Data Communication Equipment Employing Serial Binary Data Interchange
EIA/RS-422	Electrical Characteristics of Balanced Voltage Digital Interface Circuits
NEMA ICS 6	Enclosures for Industrial Controls and Systems

12-24-3 **ENVIRONMENTAL CONDITIONS:**

Ambient Temperature Range: 0^0 C to $+50^0$ C.
Ambient Relative Humidity: 5 % to 95 %.

12-24-4 **ELECTRICAL REQUIREMENTS:**

The power source, normal 120V/240 VAC, 50/60 Hz will be supplied to the PLC cabinet. The cabinet shall have two redundant power supplies for the PLC System and PLC I/O's. Fluctuations in 120V AC supply of ± 10% shall be allowed in the design of the PLC system without any effect on its operations. PLC system shall tolerate a loss of power of 100 msec without any damage, misoperation or data corruption. All components of the PLC system shall have internal high voltage surge and fast transient protection as per IEEE C.37.90.1 or equivalent standards. The PLC I/O modules shall be removable and re-insertable while the power is on without any damage.

12-24-5 **HARDWARE REQUIREMENTS:**

System Cabinet:

The system cabinet shall be floor mounted, in a freestanding stainless steel enclosure with key lockable front and back doors. Each door shall be supplied with double keys. Keys shall be removable only with doors locked. Hardware for cabinet mounting and doors shall also be stainless steel. The system cabinet doors shall be removable type. A minimum 200mm high stainless steel mounting base shall be provided with removable front and back side covers. Field cable entries to cabinet shall be from bottom. Vendor to provide four AC duplex receptacles (2 on each side of front and rear side of cabinet).

Control switches, indication lights and one display panel for PLC shall be provided on the door front with non-lockable transparent heavy-duty cover to avoid accidental operation and damage from environmental conditions. The control switches and indication lights shall be heavy duty.

The PLC display panels shall display with configuration push buttons keys the following as a minimum:

- PLC diagnostics.
- All analog process inputs and controller set points in Engineering units.
- ON/OFF Status of all digital inputs and outputs.
- Calculated and accumulated flow in Engineering units.
- Percentage values of Analog outputs.

Field cable terminals shall be located in the lower section of the cabinet. PLC individual I/O fuses shall be incorporated on field cable terminals. Easy accessibility and adequate spacing shall be provided for field cable terminals to accommodate wire numbers.

The PLC shall support trend and events recording up to 48 hours, logic and sequence functions as required by the specified operations.

PLC system availability shall be minimum 0.999 throughout an expected lifeline of 20 years. Probability of failure on demand (PFD) shall be less than 12-^{3}.

PLC shall be capable of performing standard control algorithms, PID controls, totalization, summation, sequencing logic events recording and remote uploading / downloading of programs and full system diagnostics.

Field Devices connected to PLC:

All digital input signals shall be volt free contacts.
Outputs for status indication lights shall be minimum 0.5 Amps.

Commissioning Equipment:

All commissioning equipment shall be provided by Vendor.

12-24-6 **MAINTENANCE REQUIREMENTS:**

Vendor shall provide a list of special tools and test equipment (including pricing and model numbers) required to properly maintain the PLC and the associated equipments. Vendor shall include a comprehensive spare parts list with unit prices. The Vendor shall indicate the recommended quantities for duration of two (2) years operation. Spares shall be locally stocked to be supplied at short notice during startup and commissioning. Vendor shall provide prices and define the necessary consumable (fuses, etc.) necessary for one year continuous operation. Vendor shall supply and describe the capabilities of all available diagnostic programs used for trouble shooting.

12-24-7 **SYSTEM EXPANSION CAPABILITIES**

Constraints on potential system expansion shall be stated. Future I/O expandability and spare memory capacity shall be addressed. The PLC shall be possible to upgrade for newer releases without the change or upgrade of I/O modules. The PLC I/O expansion shall be add-on modules.

12-24-8 **TESTING AND INSPECTION:**

Testing will be a functional test with all components powered and will be performed with the assistance of the PLC Vendor's personnel. The test shall verify the wiring of the I/O points.

ATTACHMENT I - PLC SPECIFICATION SHEET

Requirement		
Mounting		Free Standing
Enclosure Material		Stainless Steel (NEMA 4)
Ambient Temperature		0^{o}C to +50^{o}C
Relative Humidity %		5 % to 95%
Scan Time		100 msec or Less
Power Supply Input		120/240 VAC, 50/60 Hz.
Communication Requirements		(Note-1)
Control Algorithm PLC	PID	Yes
	Closed Loop	Yes
	Open Loop	Yes
	Logic & Sequence	Yes
	Flow Computation	Yes
No. of Archived Data Points		All

Note-1: Communication Requirements

The controller shall support multiple RS-232, RS-422 or RS-485 ports for communicating with external devices such as Operator Interface Station, Program Development Work Station or Printer. As a minimum, two RS-232 ports shall be provided.

All communication ports shall be manufacturer standard hardware and shall permit connection and disconnection without interrupting or jeopardizing system operation.

12-25 FIRE ALARM AND DETECTION SYSTEM

12-25-1 General

The contractor shall supply and install the fire alarm and detection system as herein specified and as shown on the drawings.

The system shall be of the analogue addressable type with continuous monitoring of soft analogue quantities and automatic adjustment of alarm threshold.

The installation of the system shall be in accordance with BS 5839:part 1:(1988) and the latest requirements laid by Local Civil Defence authorities.

All equipment used in the system shall, as far as practicable, be designed and provided by single manufacturer, and shall be compatible with relevant sections of the overall security systems.

12-25-2 Terminology and Definitions

Unless otherwise specified, the definitions and terms used in this specification shall be in accordance with BS 5445, BS 5446 and BS 5839 and the documents referred in these standards.

In addition, the following definitions shall apply:

1. Fire Routine

   The action to be carried out on incidence of a fire alarm, which have been agreed with the Local Fire Authorities. This includes the method of operation of the fire alarm system, including the system responses and stages and interaction with other related systems.

2. Analogue/Addressable System

   Each detector in addition to being addressable outputs a digitally encoded "Analogue' signal which varies in the `short-term' due to fault and alarm conditions and in the `long-term' due to environmental soiling.

12-25-3 Environment

Unless otherwise specified, all equipment used in the system shall be suitable for continuous operation in the following ambient conditions:-

Temperature	:	-0^{O}C to +40^{O}C
Relative humidity	:	0% to 95%, Non-condensing.
Barometric pressure	:	86 Kpa to 106 Kpa.

12-25-4 **System Features**

The system shall consist of equipment provided for receiving and indicating all signals initiated from the associated sensors or manual call points and activating alarm sounders and signaling devices.

Monitoring of detection and alarm circuit shall comply with BS 5839 Part 1.

The system shall be capable of future expansion without obsoleting any of the original equipment.

Control panels shall be of modular design with plug in Loop cards. Each loop card shall operate independently of other loop cards. The operation of control panel in fault or alarm conditions shall be assisted by guided instructions with visual indicators on the control buttons.

Facility for testing the sensors and manual call points of any loop, without affecting the function of other loops of the system shall be available.

A system of alarm verification shall be provided to minimize false alarms.

The system shall operate on 24 Volts D.C. suppressed and polarized power supply.

The control panel shall provide a 24 Volts DC output and volt free relay contacts for remote fire signals and remote fault signals.

Multiplexed outputs shall be provided on the control panel to give the flexibility of connecting the same to repeater and annunciator panels.

Local audible alarm at the control panel shall distinct for fire detection alarms and fire protection system alarms.

The control panel shall be capable of processing and evaluating signals from analogue addressable fire sensors, manual call points and auxiliary systems.

It shall be possible to over-ride delayed alarm signals to the Local Civil Defence, Authorities (if required) by call points designated for evacuation purposes.

System shall be of soft addressable type, i.e. addressing of all devices shall be done automatically from the control panel, whereby use of hard switches to set addresses in eliminated.

All system components and devices shall be connected to a 2-wire loop circuit with each component having its own individual built in isolator. Removal or disconnection of any component from the loop shall not affect the functioning and performance of other components and the system.

Dedicated telephone lines (if available) for transmission of emergency calls shall not be used for any other purpose.

Control panel shall be of the wall mounted type with modular arrangement.

In case of power failure the system shall automatically change over to the sealed lead acid stand-by battery system.

The sensitivity of the detectors shall have the capability to be changed (if required) from the Control panel.

12-25-5 **Control Panel**

The Control panel shall be constructed of sheet steel of colour to the approval of Local Civil Defence Authorities and/or Engineer. The control panel shall include but not limited to the following:

- Enhanced display and control functions.
- Alarm operation, fire control outputs and repeater mimic displays.
- Modular design for maximum reliability and flexibility.
- Functional enclosure.

The control panel shall include a power supply module to provide a filtered and regulated source of power to provide additional power wherever supplementary power is required within the system. It shall include sealed batteries a non-interchangeable output fuse and key reset automatic transfer to standby on power failure.

Control panel shall in addition have audible signal and lamp to indicate AC failure of the charger. All identifications shall be both in English and in Arabic. The Control panel shall include but not limited to the following:

- Control board containing general fire and fault LED's, LCD alpha numeric display, user controls, remote signal and fault signal relays and auxiliary relays.
- Power supply unit.
- Mother board.
- Digital display.
- Key board

Any correction in labels shall be carried out from the built-in keyboard of FACP.

Repeater panel shall incorporate visual display unit (VDU) which shall display the same information being displayed on the VDU of the main FACP.

12-25-6 **Repeater Panel**

The repeater panel shall permit the remote status signalling of fire alarm devices and shall be connected to the main control panel.

The control panel shall have an interface to allow the connection of the repeater panel via 3-wires. The repeater panel shall be supplied with communication interfaces and shall match the style of the control panel.

The repeater panel shall be recessed with a stainless steel front cover. It shall contain a reset pushbutton, trouble lamp, trouble buzzer and push button trouble silence switch.

12-25-7 **Out puts**

Individual volt-free relay contact outputs shall be provided to perform specific automatic functions as specified and as required by Local Fire Authorities. The functions shall be programmable. Contacts shall have a minimum rating of 3 amp at 24 Volts Dc. The initiation of an evacuate alarm shall send signals to operate ancillary plant as specified and as required.

12-25-8 **Optical Smoke Detectors**

The optical smoke detectors shall be of the analogue soft addressable type and shall be capable of detecting visible combustion gases from fires. Optical smoke detectors shall comply with BS 5445:part 7 and shall have a sensitivity sufficient to be classified as "A" in BS 5445: Part 9 and Test fires TF2 and TF3.

The optical smoke detectors shall employ the forward light-scatter principle using optical components operating at a wave length of 0.94 nm. Detectors shall have built-in isolator.

The design of optical smoke detectors sensing chamber shall be optimized to minimize the effect of dust deposits over a period of time. The detectors shall incorporate screens to prevent all but the very small insects entering the sensing chamber. The optical smoke sensors shall have high resistance to contamination and corrosion.

The electronic assembly of optical detectors shall be encapsulated in high resistivity epoxy resin.

The optical smoke detectors shall include RFI screening and feed-through connecting components to minimize the effect of radiated and conducted electrical interferences.

The optical smoke detector shall incorporate a LED clearly visible from the outside, to provide indication of alarm actuation.

12-25-9 **Heat Detectors**

The heat detectors shall be of the analogue soft addressable type. They shall be capable of detecting rapid rise in temperature and fixed absolute temperature. The detectors shall have built-in isolator.

The heat detectors shall meet the requirements of either BS 5444:part 5 for detectors suitable for normal environment or BS 5445:part 8 for sensors for high ambient temperature applications. The heat detectors shall employ two heat sensing elements with different thermal characteristics to provide rate of rise dependent response.

The temperature sensing elements and circuitry of heat sensors shall be coated with epoxy resin to provide environmental protection.

The heat detectors shall include RFI screening afeed-through connecting component to minimize the effect of radiated and conducted electrical interferences.

The heat detectors shall incorporate LED, clearly visible form outside to provide indication of alarm actuation.

12-25-10 **Addressable Manual Call Points**

Soft Addressable manual call points shall monitor and signal to the control and indicating equipment, the status of a switch operation by a "break glass" assembly. The addressable manual call point shall comply with BS 5839:part 2 and shall incorporate a built-in isolator.

The addressable call points shall be capable of operating by means of thumb pressure and not require a hammer.

The addressable call points shall be capable of being mounted in a weatherproof casing with ingress protection to IP 66. (wherever required)

The addressable call points shall incorporate a mechanism to interrupt the normal addressable loop scan to provide all alarm response within less than 1 second and shall be capable of being tested using a special key, without the need of shattering the glass.

The addressable call points shall be field programmable to trigger either an alert or an evacuate response from the central indicating equipment. The addressable call points shall provide an integral LED to indicate activation.

All inscriptions on the manual call points shall be permanently made on glass in English and Arabic.

The alarm condition shall be maintained until reset by an authorized person by means of a special tool provided for that purpose.

12-25-11 **Addressable Relay Output Module**

The addressable relay output module shall provide a voltfree changeover relay contacts operated by command from control and indicating equipment. The contacts of the addressable relay output module shall be rated at 1 amp at 24 volt DC. The module shall monitor the relay coil for open circuit and transmit the fault signal to control and indicating equipment.

The addressable relay output moudle shall be capable of deriving power for its operation, from the addressable loop. It shall have a red LED indication when the contact has operate.

12-25-12 **Addressable Contact Monitoring Module**

The addressable contact monitoring module shall provide monitoring of the status of switched input signals from either NO or NC contacts. The module shall provide a red LED indicator when a contact has operated.

The addressable contact monitor module shall be capable of deriving its power directly from the addressable loop.

12-25-13 **Isolators**

All system devices shall incorporate built-in isolators.

12-25-14 **Alarm Bells**

Bells shall have under dome solenoid gongs, red in color 6" diameter.

Bells shall be manufactured from sturdy die cast aluminium housing.

Bells shall be surface mounted, wiring shall be fully supervised.

Bells shall be DC vibrating type, with a minimum 65 db (A) or 5 db (A) above any other noise likely to persist for a period longer than 30 seconds as required by BS 5839. It shall produce a 75 db (A) in spaces used for sleeping accommodation, as required by BS 5839.

The alarm sound frequency shall lie between 500 Hz o 1000 Hz as required by BS 5839.

12-25-15 **Battery/Charger Console**

Battery/Charger console shall be provided where it is not an integral part of the control panel and in which case it shall be a completely self-contained console enclosing both sealed lead acid batteries and automatic battery charger for dc power.

The charger shall be two-rate constant potential unit maintaining the batteries fully charged under all service conditions. After an AC power failure longer than 10 seconds, a timer shall automatically switch the charger to its high-rate mode. Following the predetermined high-rate charge period, the timer shall automatically return the batteries to float charge. A remote initiation of the timed high-rate charge mode shall be possible.

The front of the cabinet shall be provided with hinged doors held closed by magnetic catches. Built-in stepped steel shelves shall position the rows of translucent plastic cells for visual check of electrolyte levels.

Access to the charger compartment shall be by a lift-off top cover, held in place with screws.

The unit shall be ventilated through louvers.

The cabinet shall be made of sheet steel finished in baked gray enamel.

The unit shall be provided with float potentiometer, high-rate potentiometer, ac & dc fuses, ac failure alarm relay, 24-hour automatic timer, earth detectors, ac pilot light, etc.

12-25-16 **CABLES - FIRE ALARM**

a) Conductors shall be of solid or standard plain annealed copper to BS 6360 and shall have a minimum of 1.5mm2 cross-section.

b) Insulation shall be extruded silicone rubber insulation, to BS 6899, 0.6mm radial thickness.

c) Sheath shall be of aluminium/PVC laminate and PVC composite sheath with tinned copper circuit protective conductor or drain wire.

d) The PVC/aluminium sheath shall consist of a PVC coated aluminium tape applied longitudinally and foiled around the cores/pairs to give an overlap. A hard grade PVC compound is applied by extrusion directly over the coated aluminium tape to adhere to the PVC coating and form a composite sheath having excellent moisture barrier, electrostatic high frequency screening properties and superior hoop strength.

e) Over sheath: X-Flam 15 flame retardant PVC sheath. The PVC sheath shall have a good resistance to impact, abrasion, weather, oil, greases, acids, alkalis and a wide range of chemicals.

f) Voltage Ratings: Fire alarm cables shall be rated 300/500V.

g) Operating Temperatures: Fire alarm cables shall intended for operation at a maximum sheath temperature of 70 C.

h) The Contractor shall check for voltage drops and shall provide larger size cable if necessary for the proper operation of the system.

i) Number of cores shall be 20% more than what is required by the system.

12-26 TELEPHONE SYSTEM (PABX)

12-26-1 GENERAL

The Contractor shall supply and install the telephone system as shown on the drawings and as herein specified. The system shall include conduits, conduit fittings, telephone outlet, cable, telephone handset, telephone box and all necessary parts to install a complete telephone system.

All work relating to the telephone system shall conform to the requirements of the local telephone authorities.

12-26-2 TELEPHONE BOX

Telephone box shall be surface mounting weatherproof unit with necessary terminal blocks to connect telephone authorities incoming cable.

12-26-3 TELEPHONE OUTLETS

Telephone outlet shall consist of terminal blocks of high insulating phenolic block with non-ferrous screws and straps fixed inside wall box. Outlet shall be cord-outlet type.

12-26-4 HANDSET

Handset shall be of moulded high impact thermoplastic casing pushbutton dial type.

12-26-5 CABLE

Cable shall be PVC insulated and PVC sheathed 4 core. Diameter of conductor shall not be less than 0.6mm.

12-26-6 TELEPHONE CABINETS

Telephone cabinets shall be a general purpose type enclosure for surface mounting, of size and location as indicated on the Drawings.

Cabinets shall house all terminal blocks necessary for terminating and tapping telephone cables. Ample spare terminals shall be provided.

All telephone cabinets shall have an identifying name plate of laminated phenolic material with 8mm white letters on a black background. Nomenclature shall be as instructed or agreed upon with the Engineer.

Cabinet shall be fabricated from minimum 1.5mm thick galvanized sheet steel, galvanized after fabrication.

Joints shall be welded and reinforced where required.

Cover shall be fabricated from a minimum 2 mm cold rolled sheet steel.

Cover shall be fastened to the cabinet flanges by the use of countersunk flathead machine screws or overhead machine screws with finishing washers.

Exterior of surface mounted cabinet shall be given a minimum of one coat of gray enamel.

Trim shall be given one prime coat and one finish coat gray lacquer.

Concealed surfaces of flush mounted cabinets shall be given field application of emulsified asphalt prior to installation.

12-26-7 SCOPE DESCRIPTION

1. The Contractor shall furnish all telecommunications cabling equipment and materials whether specifically mentioned herein or not, to ensure a complete and operating system. The Contractor shall provide all conduit, junction boxes, and cable ladders where specified for telecommunications cabling.

2. The Contractor shall generate all shop drawings and information for the complete installation and wiring of the system. The Contractor shall provide (or sub-contract for) the on-site installation and wiring, and shall provide on-going supervision and coordination during the implementation phase.

3. The Contractor shall be responsible for the initial adjustment of the systems as herein prescribed and shall provide all test equipment for the system checkout and acceptance tests.

4. The Contractor shall provide on-the-job training in the operation and maintenance of the system for personnel designated by the Client.

12-26-8 EPABX

A. General

Furnish and install a complete telephone system including Telephone distribution components, (EPABX), operators consoles, Telephone

Submit data for approval including complete technical data and manufacturer's catalogues for all equipment and materials.

B. **EPABX**

EPABX is to be of the data/voice communication type, fully electronic, digital stored prog. Using a single Twisted pair cable. Options: such as cordless phones, voice messaging, paging.

C. **EPABX shall be modular design**

1. Noise level less than 40 DB at 1m distance
2. Program data stored in RAM with none volatille back-up.
3. Program should be done from standard PC or from Digital Telephone, and Remotely Via built in modem.
4. Inter connection between PABX and MDF shall be by means of prefabricated front connected plug in cables.
5. PCM coding of voice frequency according to CCITT/A-Low.
6. Numbering Scheme: One to Four digit code.
7. Any combination of Anologue, DTMF, push button and Digital Telephone Set shall be possible.
8. Current feed shall be 2 x 400 ohm. and operating voltage shall be 48V with tolerance + or - 6 V.

D. **System Capacity**

System Capacity should be expandable up to 64 extensions and up to 2 operator consoles.

E. **Trunk Lines**

The exchange shall permit the connection of the following Trunk circuits:

- internal extensions (as shown on drawings).
- city trunk lines (as shown on drawings).

F. **Extension**

Operator Console, System Telephone and Analogue Telephone shall be operated and powered via a single pair of wire.

G. **Operator Function:**

1. Call identification.
2. Call parking loops minimum 4 lines
3. Queu indication.
4. Serial calls.
5. Metered calls.
6. Diversion bypass.
7. Auto and manual call accepting and extending.
8. Forced released, etc.

H. **System Features:**

1. Alternative answering position.
2. Background music.
3. Classes of services (COS).
4. Control of call charges (individual call metering, call information logging).
5. Diagnostic functions and alarm indication.
6. Differentiated ringing (internal, external, special ring signal).
7. direct inward dialing (DID).
8. External route selection (incoming/outgoing).
9. Flexible numbering (1.... 4 digits).
10. Least cost routing.
11. Multi-user operation (tenants).
12. Music on hold.
13. Networking features.
14. Night service.
15. Power failure transfer.
16. Printout of telephone directory.
17. Programming of system parameters.
18. Recall.
19. Recorded announcements.
20. Remote service and maintenance (active alarm, heart beat supervision, call back).
21. Re-routing (busy, no answer).
22. Tone (DTMF) and pulse dialing (internal and external).
23. Traffic authorization.
24. Trunk call discrimination (TCD).

I. **Extension Features:**

1. Abbreviated dialling (common and individual).
2. Account code.
3. Authorization code.
4. Automatic call back.
5. Bypassing of call diversion and follow me.
6. Call metering (actual call, last call and accumulated fee).
7. Call pick-up (individual, group, common).
8. Call waiting.
9. Camp on.
10. Conference.
11. Dedicated intercom line.
12. Dedicated trunk line.
13. Diversion (direct, bust, no answer).
14. Double line access.
15. Inquiry (internal and external).
16. Executive / Secretary functions.
17. Follow me (internal, external).
18. Free on second access.

19. Group hunting.
20. Handsfree conversation.
21. Hot line (immediate or delayed).
22. Immediate speech connection.
23. Information handling system (voice, free test, pre-defined text).
24. Intrusion.
25. Last number redial.
26. Loudspeaker paging.
27. Loudspeaking.
28. Menu keys.
29. Message handling system (call me, voice, free text).
30. Monitoring.
31. Name call.
32. Name indication on display.
33. Parking (common, individual).
34. Post-dialling with DTMF for digital telephones.
35. Recall of unanswered transferred calls.
36. Reminder call.
37. Saved number redial.
38. Supervision function (busty indication, call pick-up, direct call) for extensions and trunk/tie lines.
39. Team functions.
40. Telephone directory for internal and external numbers.
41. Temperature indication on display.
42. transfer of calls before and after being answered.

J. **Power Equipment and Consumption:**

1. The DC power supplied to the system shall be 48 V.
2. Other voltage used in the system shall be converted from the 48V supplying separate AC/DC converters.
3. The PABX shall be provided with a rectifier and battery performing on 220V/50Hz permissible variations of -20 to + 10% for the mains voltage.
4. Back-up for at least 8 hours service with maximum traffic shall be included, and recharged within 3 hours.

12-27 MONITORING AND CONTROL SYSTEM

12-27-1 SCOPE OF SUPPLY

The Contract shall include the design, submission of drawings, specifications, calculations, works testing, packing and delivery to site, off loading, installation, site testing and commissioning.

The works shall include the following:

a) The design and supply of equipment and instruments complete.
b) The design and supply of all software including any software required to configure the instruments, licences and training courses.
c) Works testing of the individual instruments and a full system integration test.
d) The installation and connection of equipment and instruments.
e) Full system commissioning and site acceptance tests of all equipment.
f) Maintenance during the 12 month defects liability period which shall commence on the date of issue of the system Taking Over Certificate.
g) Full system documentation.

12-27-2 REMOTE TERMINAL UNIT (RTU)

1. Introduction

This document is a Request description of RTU requirements and specifications control and monitor The water wells and water pumping station. These RTUs will be located indoor in enclosures at each station.

2. Description of Work

The contractor shall provide and test RTUs as detailed in these specifications.

The RTU supporting communication system consists of buried fiber optic cable, buried copper cable or microwave terminating at each RTU site.

The RTUs supplied and tested by the contractor shall be in accordance with this Specification for SCADA Remote Terminal Units.

3. Configuration

The requirement for the RTUs is that they shall be equipped to allow control and monitoring from a central location using the MODBUS ASCII protocol.

12-27-3 APPLICABLE DOCUMENTS

Equipment furnished under these specifications shall be manufactured in accordance with the latest applicable standards of ANSI, IEEE, NEC, NEMA.

12-27-4 ENVIRONMENTAL CONDITIONS

The RTU shall meet the following environmental requirements:

Temperature range: -10 deg. C to *+50 deg. C.*

b) Relative humidity: 0% to 95 % (non-condensing)

12-27-5 FUNCTIONAL SPECIFICATION

A. Hardware Requirements

The RTUs shall be low power, microprocessor based, modular, readily expandable, and equipped with sufficient volatile and non-volatile memory to accommodate the necessary data communication link to the stations via the combination fiber optic, copper, and microwave communication system. The RTUs shall consist of the following basic hardware components:

a) The basic RTU assembly for plug in cards or modules shall be for mounting on a standard 19" equipment rack within an equipment cabinet.
b) The RTUs shall be equipped for all functions (Input/Output)
c) The connection between the termination area and the modules shall be pre-wired by using ribbon cables or by any other suitable wiring practice. All external wiring shall be via connectors mounted to the RTU body.
d) The RTU shall provide battery backup to volatile memory in order to retain data during an extended loss of power.
e) The RTU shall use a 16 or 32-bit processor technology.
f) The RTU size of RAM memory shall be 2 Mbytes minimum.
g) All I/O modules shall be short-circuit protected and overload protected.
h) All RTU digital inputs shall be isolated.
i) The RTU shall be capable of being powered by a positive ground, floating 12-vdc source.
j) The RTU ports shall be equipped with a minimum of two communication ports configurable for either RS-232 or RS-485.
k) The RTU shall be equipped Ethernet port (10Base-T) for communication and remote networking.

l) The RTU shall support remote configuration and software download via the Ethernet port.

B. RTU Functional Requirements

a) The RTU shall support MODBUS PLUS, IEC 870-5T101, DNP 3.0, BSAP or equivalent to standard communication protocols.
b) The RTU shall have the facility to be remotely programmed from a master station.
c) The RTU shall support the following as a standard offering:
d) PID
e) open-loop control
f) closed-loop control
g) Logic/sequence functions
h) The RTU shall archive field data in case of loss of communication with the master.
i) The RTU shall support automatic uploading to master on communication recovery.
j) The RTU shall support as a minimum 100-msec time resolution of discrete inputs to support Sequence-of-Events functions (after signal filtering and buffering).
k) The RTU shall support Report-by-Exception and Report-All-Status data.
   1) Analog Input signals from field instruments shall be 4-20 ma currents derived from field instrument current loops.
   2) Analog Outputs scaled to 4-20 ma full-scale (unipolar), 12-bit resolution. Accuracy $\pm$ 0.1%.

C. Operating Conditions

The RTU's will be installed within indoor cabinets. The RTU shall be designed to operate without air conditioning or forced air ventilation and under the environmental conditions.

D. Communication Protocol

The master control and monitoring water well and pumping station RTU's will be located at the control room of administration Building. The following functions should be supported by the protocol:

a) The RTU shall support the Report by Exception protocol.
b) Data Information (Analog, Pulse Accumulation)
c) Supervisory Control shall be in the form of Master Station initiated controlling functions, which conform to the Check-before-Operate mode.

12-27-6 DOCUMENTATION

The Vendor shall submit fully developed hardware and software documentation for all the components and systems covered by the Purchase Order.

Scope and Organization

The Vendor shall supply bound documentation, written in English and Russian, and shall organize the manuals into a "top down" format covering the following minimum required topics:

a) General System Description
b) Technical Descriptions (to the module level)
c) Theory of Operation (to the component)
d) Operating and Adjustment Procedures
e) Installation and Commissioning Procedures
f) Corrective Maintenance Procedures (including signal flow diagrams, fault tracing diagrams, isolation procedures and expected values).
g) Troubleshooting guidelines
h) Wiring diagrams
i) Preventative Maintenance Procedures
j) Drawing and Parts list (to component level)
k) Recommended Spare Parts Lists
l) Software and Firmware Documentation.

12-27-7 100 BASE FIBER OPTIC SWITCHING HUB

1. Introduction

This section is a description of 100Base-T Fiber Optics switching hub requirements and specifications to provide backbone communications for RTU SCADA network. These switches will be located indoor in enclosures in non-air-conditioned rooms.

2. Description of Work

The contractor shall provide, install and test the switches as detailed in these specifications.

3. Environmental conditions

The switches shall meet the following environmental requirements:
a) Temperature range: -5 deg. C to *+50 deg. C.*
b) Relative humidity: 0% to 95 % (non-condensing)

4. Functional specifications

The 100Base-T fiber Optic switch shall support at least 8 ports, The switch shall provide dedicated bandwidth on each port. Each port shall have Link/Activity, 100Mbps, and Full-Duplex/Collision LEDs.
Each switch shall have four 100 Base FX Fiber optic ports, these ports shall operate using 9/125 micron single-mode fiber SC connectors and shall operate at 1550nm.
Each fiber port shall be selectable for either full- or half-duplex mode.
The switch shall have Power LED clearly indicating the status of electrical power.
The switch shall support IEEE 802.3x flow control for full-duplex and Back-Pressure flow control for half-duplex.

5. Power Supply

The switches shall be designed for operation from a nominal 220V AC.

6. UPS

Each Remote Terminal Units (RTU) shall be power via an uninterruptible power supply with a battery backup of 4 hours.

12-27-8 FIBER OPTIC CABLE SPECIFICATIONS

Fiber optic cable shall be UL-listed type OFNP; six or twelve 9/125 micron single mode fibers, each with a color-coded PVC buffer. Maximum attenuation shall be 0.05 dB/km at 1550 nm. Fiber will be complying with ITU-T recommendation G.655. The cable shall be direct buried type and should contain no metallic elements with tensile strength greater than 10N.

12-27-9 UNSCREENED TWISTED PAIR (UTP) DATA CABLE – CAT6

Specifications:	This cable meets or excess the requirement of EIA/TIA568 and TSB36.
Conductor:	24 AWG (0.511 mm nominal) solid bare copper.
Insulation:	Polyethylene, diameter 1.22 mm maximum
Pairs:	2 insulated conductors twisted together, lays varied to minimise crosstalk. 4 pairs twisted together.
Sheath:	PVC, Colour - grey, <6.35 mm overall 11 diameter.

Colour Code:	**Pair**	**Conductor 1**	**Conductor 2**
	1	Blue/White	White/Blue
	2	Orange/White	White/Orange
	3	Green/White	White/Green
	4	Brown/White	White/Brown

R.J. 45 OUTLET

The RJ-45 jack shall be designed to the following standards:

ANSITTIA/EIA 568 (and Revision Draft SP-2840A)
TIA/EIA TSB40A (Category 5 (100 MHz).
OFTEL General Approval No. 5
FCC 68.500
ISO 8877 (1987)
ENV 41001
ISO/IEC DIS 11801 (draft)
EN60 950/BS 7002
BS EN 41003

The patch cords shall be designed to meet TIA/EIA TSB40-A Category 6.

12-27-10 **PERSONAL COMPUTERS (PC)**

The Contractor shall supply personal computers to the Water Authority complete with warranties and software's licenses.

The Computers shall be of minimum Intel Pentium 4 –1.6GHz processor, 256MB upgradeable to 1GbRAM, 30Gb Hard disk drive, read/write CD drive, 128MB VGA card, integrated 10/100 NIC, 56K integrated modem, 15" TFT monitor, Windows XP professional operating system.

12-28 ELECTRICAL FIELD ACCEPTANCE TESTS

12-28-1 GENERAL

After the electrical installation is complete, tests shall be made to demonstrate that the entire system is in proper working order and in accordance with the drawings and specifications. In no case shall the tests be less than those outlined hereafter unless requested in writing by the Contractor and acceptable to the Engineer. The tests outlined herein shall be in addition to, and not substitution for, the tests of the individual items at the manufacturer's plant. Insulation and ground resistance tests shall be made before operating tests. Proper rotation shall be determined before permanent connections are made.

The cost of all tests shall be borne by the Contractor, including expense incident to retests resulting from the failure of any equipment or part which cannot meet the required specifications.

All wiring and equipment found defective, or failing to meet the specified requirements shall be replaced by the Contractor without charge, unless written acceptance for repair is given by the Engineer.

The Contractor shall furnish four copies of all test results.

The Contractor shall provide suitable electrical instruments including voltmeter, ammeter, and tachometer as calibration curves of the instruments which shall have been calibrated for these specified tests.

The Contractor shall make the necessary openings in the circuits for the testing instruments and shall place and connect all instruments, equipment and devices, necessary for the tests. Upon completion of the tests, these shall be removed and all circuits connected to their permanent condition.

Other sections of the specifications required the services of one or more manufacturer's representatives, to ensure that equipment supplied has been installed properly and adjusted to proper working order. The Contractor shall advice such representatives of all applicable tests required by this section, so that the work will be coordinated to minimize interruption and delays.

The tests shall be conducted in the presence of the Engineer's Representative and shall be subject to his acceptance. He shall be notified seven calendar days or more in advance when any test is to take place, and it shall not be started without his permission.

12-28-2 **INSULATION RESISTANCE TESTS OF CIRCUIT 600VOLT AND LESS**

After installation, all feeders and branch circuits shall be tested by the Contractor for insulation level.

Tests for insulation level shall be made by a 500-volt Megger applied between each conductor of a circuit and all other conductors of the circuit grounded. Tests on the wires and cables shall be made before they are connected to motors and other equipment.

The Contractor shall submit two copies of the test data to the Engineer. Test data shall list each circuit and the measured resistance.

12-28-3 **INSULATION RESISTANCE TESTS OF MOTORS**

After installation, the Contractor shall megger the windings of all 3-phase motors. They shall be tested in accordance with and meet the requirements of IEEE Standard No. 43 or equivalent. Two copies of the test data shall be submitted.

12-28-4 **GROUND RESISTANCE**

The Contractor shall test each entire grounding system for continuity of connections and for resistance. The ground resistance of conduits, equipment cases, and supporting frames shall not vary appreciably from that of the system as a whole.

The ground resistance of the interconnected system, or between separate systems under this contract, shall not exceed 5 ohms.

12-28-5 **OPERATING TESTS**

Each motor and associated equipment shall be tested under conditions as near as possible to normal operating conditions for as long a time as is necessary to demonstrate correct alignment, wiring capacity, speed, and satisfactory operation. The motor shall be loaded to full capacity, or as near there to as possible.

Associated equipment includes instruments, meters, relays circuit breakers, switches, and other devices in substations, motor control centers, panelboards, control and instrumentation panels, etc., directly associated with the motor being tested.

Where tests of any of the above-referenced equipment are included in other sections of the specifications, the Contractor shall coordinate the tests to the satisfaction of the Engineer's Representative to avoid duplication and conflict between tests.