REPUBLIC OF LEBANON

MINISTRY OF ENERGY AND WATER

COUNCIL FOR DEVELOPMENT AND RECONSTRUCTION

CONTRACT No 19841

CONSTRUCTION OF DRILLING WATER WELLS, PUMPING STATIONS AND LIFT LINES IN BEINO AND DEIR NBOUH AREAS

VOLUME 3-2

TECHNICAL SPECIFICATIONS

Part 3 - Mechanical Works
Part 4 - Electrical Works
Part 5 - Instrumentation and Control
Part 6 - Testing and Commissioning
Part 7 – Boreholes

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MINISTRY OF ENERGY AND WATER

COUNCIL FOR DEVELOPMENT AND RECONSTRUCTION

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PART 3

MECHANICAL WORKS

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301. GENERAL MECHANICAL SPECIFICATION REQUIREMENTS

301.1 ABBREVIATIONS

The following abbreviations are used in these documents :

1/head/day	liters per head per day
AC	Asbestos Cement
AGMA	American Gear Manufacturer’s Association
AOD	Above ordnance datum
BS	British Standard
CDR	Council for Development and Reconstruction.
CFM	cubic feet per minute
Ch	Chainage
CMR	Continuos Maximum Rating
CP	Code of Practice
CPU	Central Processing Unit
DI	Ductile Iron
DIN	Deutsch Industrie Normen
DOV	Double Orifice Valve
DPSK	Differential Phase Shift Keying
DTU	Documents Techniques Unifiés
EDL	Electricity of Lebanon
EMC	Electromagnetic Compatibility
EOH	End of hole.
FDS	Functional Design Specification
FIDIC	Federation Internationale des Ingénieurs- Conseils
FSK	Frequency Shift Keying
g	acceleration due to gravity ($9.807 m/s^2$)
GL	Ground level
gpm	gallons per minute
gr	gram
GRP	Glass Reinforced Plastic
GTSD	General Technical Specification Document
hr	hour
I/O	Input / Output
IEE	Institute of Electrical Engineer
ISO	International Standards Organization
ITS	Institute of Technical Studies
kgf	kilogram force
kPa	kilo Pascal
kVA	kilovolt-ampere
kW	kilowatts
kWh	kilowatt hour
LED	Light Emanating Diode
m	meters
m/s^2	meters per second per second
m^3	cubic meters
m^3/day	cubic meters per day
MDPE	Medium Density Polyethylene
mgd	million gallons per day

mhd	meters head
mm	millimeters
NFE	Normes Françaises - (Electrical)
NLQ	Near Letter Quality
NPSH	Net Positive Suction Head
PS	Particular Specification
PTT	Poste de Téléphone et de Télégraphe
PVC	Polyvinyl Chloride
PWL	Pumping Water Level
RAM	Random Access Memory
RBC	Rotating Biological Contractor
RTR	Reinforced Thermoplastic Resin
RTU	Remote Terminal Unit
SCADA	System Control And Data Acquisition
SOV	Single Orifice Valve
SPTD	Signal Pole Double Throw
SSU	System Supervisory Unit
SWL	Static Water Level
TDH	Total Dynamic Head
TDM	Time Division Multiplex
TEFC	Totally Enclosed Fan Cooled
UHF	Ultra High Frequency
UPS	Uninterrupted Power Supply
UPVE	Unsaturated Polyvinyl Chloride
VDU	Video Display Unit
VGA	Video Graphics Array
VHF	Very High Frequency
VHS	Video Home System

301.2 GENERAL

The following clauses shall specify general mechanical requirements and standards of workmanship for equipment and installations. These general specification clauses shall apply where appropriate except where particularly redefined in the individual sections of the specification.

301.3 FINISH

All covers, flanges and joints shall be properly faced, bored, fitted, hollowed, mounted or chamfered as the case may be, according to the best approved practice and all working parts of the plant and other apparatus, shall similarly be well and accurately fitted, finished, fixed and adjusted.

301.4 CALCULATIONS AND CONSTRAINTS

All parts shall be designed according to the most unfavorable conditions they might encounter during operation, the international regulations and standards and the specifications of the present tender document.

Parts shall be oversized and designed to withstand maximal strains and pressures occuring during operation; ensure a good anchorage and a perfect distribution of strains, and withstand dynamic stresses, untimely shut downs, etc...

Mechanical parts shall have a safety coefficient under normal working conditions of minimum 5 according to the breaking load of the metal used (provided that the adopted international standards do not impose another coefficient).

Welded parts likely to undergo great stresses shall be annealed.

Flanges and bolting materials shall be oversized and shall not generate, when used, elastic lengthenings incompatible with the sealing of the assemblings.

301.5 ASSEMBLING AND DISASSEMBLING

Assembling and disassembling for usual maintenance purposes shall be made as easy as possible, without having to modify any part of the structure. Thus, all junctions and branchings of pipes which diameter exceeds 2”1/2, with bends, T-joints and the like, shall be made exclusively by means of flanges and/or removable couplings, if need be.

301.6 GENERAL GUARANTEES AGAINST WEAR

The Contractor shall acknowledge the condition of the water used, and that, under normal working conditions, the supplied equipment shall not show any abnormal sign of wear.

Main elements subject to significant wear due to water, shall be fitted with removable parts. These elements and parts, shall be made from a resistant metal.

301.7 LIFESPAN

Equipment, especially outdoor plants shall be resistant to physical and chemical phenomena likely to reduce their lifespan.

Following are the main phenomena to be taken into consideration :

301.7.1 Oxydation

When selecting and using the materials and components of the equipment, the following conditions shall be taken into account :

- All sets of screws shall be coated with cadmium, bichromate, or zinc.
- Metalworks shall be of bronze, brass, copper alloy. Connections between metalworks and supports are designed to prevent any corrosion.

- The use of inflammable moulded plastic materials is permitted for small sets (small boxes, telephones, etc....) which do not undergo mechanical or thermal stresses.
- Electrical equipment shall be fixed on galvanized and painted iron mounts, frameworks or runs.
- Protection sleeves are of aluminium
- Gratings shall be hot dip galvanized
- Electrical equipment and components shall be internally and externally tropicalized.

Insulators of electrical equipment, and wedging and securing devices shall be of isolation class F, (unless otherwise specified). The windings shall have a vacuum double coating for tropicalized treatment.

It shall not be permitted to use any hygroscopic or likely to mould material, namely, cotton, asbestos, bakelite, shellac, natural rubber.

- Dielectric oil of machines shall not be put in direct contact with air.
- The use of heat resistances is mandatory in installed boxes and switchboards (condensation).
- Precautions shall be taken in order to avoid oxydation during transport and on site storage of the equipment. Packings suitable for sea transport, protective paintings or coatings and other means (terminals or cable ends weldings, tips or caps of pipes,...) must be used.

301.7.2 Corrosion caused by water

Equipment, in contact with water, shall be of metals and alloys, which nature, physical and chemical characteristics and conditions of use are capable to withstand corrosion of water.

Complementary measures of mechanical, chemical, and electrochemical protections (coating with paint, plastic deposit, zinc, or electrolytic cells) shall be taken, when selecting materials.

Cast iron parts, as long as the use of this material is permitted, shall be protected by a special coating in order to avoid graphitization.

Steel parts shall be coated, preferably, with an appropriate alloy.

301.7.3 Temperature

Materials - in particular insulators and couplings - shall be chosen to ensure a good mechanical lifespan, regardless of the temperature, the mechanical constraints and the temperature gradients due to their operation or the climatic conditions.

301.7.4 Heating

Temperature of bearings, reducers, and other mechanical parts shall not exceed 80°C during normal operation.

Electrical insulating materials shall not be subject to heating exceeding that of class B.

301.7.5 Dirt

Heat exchangers, coolers, etc... shall be calculated with a 5% margin on the surfaces. The maximum proportion of dirt corresponds to 15% decrease in the exchange coefficient.

301.7.6 Adverse weather

Installed equipment and machinery shall be designed to prevent any penetration, accumulation, water impregnation or encrustation caused by air or water entrained products (dust, sand, earth, ashes, vegetal detritus, insects, etc...)

Slopes and flows are designed accordingly.

Electrical, electronic or mechanical equipment, which cannot withstand adverse weather, shall be installed indoors, inside switchboards or boxes impervious to water jets and dust, and fitted with ventilation holes and necessary heating or ventilation means.

The external protective coating for pipes, valves and fittings or equipment shall be designed to be impervious to rain and water jets, without impeding dissassembling for inspection or maintenance purposes.

Great care shall be taken to ensure the sealing of bearings, pipes, casings, sheaths, electrical plugs, probes, and junctions. No leak is permissible.

Seal packings shall preserve their quality regardless of the temperature, temperature gradients, and industrial lubricants they are subject to.

Sliding surfaces, whether greased or not, shall be protected to prevent dust deposits which may cause plugging.

301.8 FOUNDATIONS, BUILDERS WORK AND SETTING OF MACHINERY

The Contractor shall ensure that the positions of foundations for machinery plinths, holding-down bolts and the setting of machinery are carried out in accordance with the approved machinery drawings and shall be held responsible for the accuracy of the particulars given thereon.

The Contractor shall, upon receipt of the necessary approved drawings for the machinery, supervise the construction of all the necessary foundations and bases for the various items of plant, including the forming of holes and chases for pipework, cabling, conduit, ragbolts and where necessary, the building in of foundation bolts and sundry items of plant, all in accordance with the drawings. Spaces shall be left between the concrete and bedplates etc. for grouting and building in. The Contractor shall provide all necessary templates for fixing the positions of bolt holes, etc.

The machinery shall be mounted on flat steel packings of a thickness selected to take up variations in the level of the concrete foundations.

The packings shall be bedded by chipping or grinding of the concrete surface.

Only one packing of selected thickness shall be used at each location, which shall be adjacent to each holding down bolt. The number of shims shall not exceed two at each location and the thickness of each shim shall not exceed 3 mm.

The machinery shall be aligned, leveled and pulled down by the nuts of the holding down bolts with a spanner of normal length, and no grout shall be applied until the machinery has been run and checked by the Engineer for stability and vibration.

The Contractor shall clean the concrete and prepare for grouting up after the pumps, motors, girders, etc., have been finally fixed and packed up.

The Contractor shall supervise the grouting and building in of the equipment and shall take all responsibility for the satisfactory nature of this work.

The Contractor shall arrange for the delivery of all items of equipment that are required to be "built in" the civil works, as required by the construction program and shall arrange for a representative to be in attendance during the progress of such works.

When the foundations are completed and are in a suitable condition or when directed by the Engineer, the Contractor shall install the plant, which when leveled-up shall be grouted, by the Civil Contractor, to the Contractors instructions.

301.9 LOCATION AND ALIGNMENT

Where separate items of interconnected plant, such as motors, couplings, gearboxes and similar items depend upon correct alignment for satisfactory operation, then each and every item shall be positively located in its correct operational position by means of dowels, locating pins, fitted bolts or other approved means to ensure that correct re-alignment can be easily achieved when re-assembling the items after removal for overhauls.

301.10 FASTENINGS TO CONCRETE OR MASONRY

Anchor bolts for the fixing of small items shall be of the torque-expanded type of approved make, installed strictly in accordance with the manufacturer's instructions. The size of hole required in the Civil work shall not exceed 38mm.

Where the base material will not withstand the expansion stresses imposed by the torque-expanded type or where the highest degree of resistance to vibration is required an approved type of chemically bonded anchor bolt may be used.

The minimum distance from any concrete edge shall be 100mm for expanding type fixings and 75mm for embedded bolts.

301.11 BASEPLATES

Separately mounted items of plant which are required to maintain an accurate alignment shall be mounted on a common baseplate, together with all associated items and guards.

The baseplate shall be of rigid construction, machined on all mating surfaces and drilled for foundation fixings. Machined datum faces shall be provided and levelling facilities incorporated in the underside.

Provision shall be made for the easy removal of any section of the drive and positive re-alignment using dowels or other approved means. Shims and packings shall be kept to a minimum and clearly identified for re-assembly.

All drain points on the assembled plant are to have easy access and drain piping shall extend beyond the baseplate.

301.12 PROVISION FOR HANDLING

Suitable provision approved by the Engineer shall be made by the Contractor to facilitate the handling of all items in excess of 36kgf.

Any item weighing one tonne or over and which may be required to be lifted during operation and maintenance shall be appropriately marked with its weight.

301.13 GUARDS

Adequate guards shall be supplied and installed throughout the installation to cover drive mechanism. All rotating and reciprocating parts, drive belts, etc. shall be securely shrouded to the satisfaction of the Engineer to ensure the complete safety for both maintenance and operating personnel. However, whilst all such guards shall be of adequate and substantial construction they shall also be readily removable for gaining access to the plant without the need for first removing or displacing any major item of plant.

301.14 BALANCING

All rotating parts of the machinery shall be statically and dynamically balanced unless otherwise agreed in writing by the Engineer. The complete rotating assembly shall be designed such that any critical speeds are outside the duty running speed range of the machine.

301.15 LUBRICATION

Any components requiring manual lubrication shall be provided with greasing nipples of an approved type mounted on a panel and identified.

A remotely mounted electrically operated lubricator of approved type shall be provided to serve components, if any, requiring continuous lubrication by external mechanical means.

The lubrication tubes, if any, shall be of approved material suitable for high pressure use.

The Contractor shall include for all grease and oil required for testing at works and site.

The first filling after tests shall be provided by the Contractor who shall submit details of his recommended lubricants, which shall be available from any of the major oil companies, for approval by the Engineer.

All bearing surfaces shall be properly charged with grease before the plant is operated.

301.16 NAMEPLATES AND LABELS

Instruction plates, nameplates and labels shall be provided for all items of the plant giving particulars of duty, size, serial number and full information for identification and operation. Their construction and engraving shall be to the Engineer's approval.

301.17 PLANT REFERENCES

After final painting, all plant items shall be identified by a unique reference character as detailed on the specification drawings or otherwise specified. Such references to be affixed in a prominent position on the plant body with characters not less than 100mm high or as otherwise specified. Characters shall be bold capital letters and/or numerals. The abbreviation `No' shall not be used.

Unit references shall include any associated main and auxiliary drives and shall follow a logical sequence based on layout or history. In any particular installation, a set of similar duty drives where any number of units may run shall be suffixed 1, 2, 3, 4 etc., whereas alternative drives for the same duty where only one unit may run (ie.duty/standby) shall be suffixed A & B.

301.18 TOOLS AND TACKLE FOR MAINTENANCE

The Contractor shall supply a complete set of any special tools and other equipment necessary for the dismantling, re-erection and adjustment of the plant.

The tools provided shall be in new condition, adequately labelled as to their use and contained in stout and suitable padlocked boxes. The Engineer's instructions as to who shall be the recipient of the tools shall be sought before delivery is made.

Any special slings required shall be provided and clearly marked by embossed labels to show safe working loads. Test certificates shall be provided where applicable.

301.19 LOCKS AND KEYS FOR MECHANICAL PLANT

All locks of the same size shall be of the same type and manufacture but having different keys.

Three keys shall be provided for each lock.

Each key shall have permanently attached to it an embossed brass label stating the following:

a) Key number
b) Location of lock/Item of equipment

301.20 NOISE AND VIBRATION

All plant shall run with the least practicable amount of noise. The contact shall insulate the material when necessary.

All plant shall run without undue vibration. All parts supplied shall be designed such that when being used, opened or partially opened (under normal operating conditions) the dynamic stresses shall not cause any vibration, nor deformation.

Vibration levels shall not exceed these set cut in ISO 2372 for the particular type of equipment.

The double amplitude on the bearings shall not exceed 20 microns under normal working conditions.

Analytical and safety instruments, as well as control mechanisms shall be systematically protected from vibrations, and when necessary, installed far from machines (on independent support or panels). Particular precautions shall be taken in the event of a relay likely to lead untimely opening and closing of electrical contacts.

The equipment supplied shall never cause any vibration in masonries. Machines shall operate as quietly as possible.

To meet the environmental requirements, the Contractor shall provide all necessary equipment to meet the following conditions, based on the site layout shown on the specification drawings and with 75% of the plant running simultaneously:

a) the noise level generated at the site boundary by any new plant shall not exceed that generated by the existing plant, or the maximum background noise measured between 12 p.m. and 4 a.m. plus 5 dB. Background noise is defined as being the L_{A90} level, that is the level exceeded for 90% of the measurement period.

b) Warning notices shall be provided at all entrances to rooms where the noise level will exceed 75 dB (A).

301.21 BEARINGS AND LUBRICATORS

Ball and roller bearings shall be rated for a minimum plant life of 10 years, with due consideration being given to the number of starts and periods of operating under conditions of maximum dynamic axial and radial loading. The size of bearing shall be not less than that calculated for a minimum L10 basic rating life in accordance with BS.5512 Part 1.

Taking into account all considerations of reliability, materials of manufacture and operating conditions.

All bearings shall be generously rated and sized to ensure satisfactory and stable running without vibration under all conditions of operation for a minimum life of 100.000 hours running. They shall be efficiently lubricated and adequately protected from ingress of moisture, dust and sand and the particular climatic conditions prevalent at the site. All bearings shall be to ISO standard SI unit dimension where practicable.

All ball or roller bearings, including those supplied as "sealed for life" shall be arranged for grease gun lubrication and a suitable high pressure grease gun shall be supplied. All grease nipples shall be standardised.

Adequate and as far as possible, automatic means of lubrication shall be provided for all moving parts. The position of all greasing and oiling points shall be arranged so as to be readily accessible for routing servicing. Where necessary to achieve this, suitable access platforms shall be provided.

The type of lubricant and intervals of lubrication, which shall be kept to a minimum (not less than nine days), for each individual item of plant shall be entered on a working schedule, which shall form part of the Operation and Maintenance instructions.

A list of recommended lubricants and their equivalents shall be entered in the operation and maintenance instructions.

301.22 FROST PROTECTION

The plant shall be adequately protected against damage from freezing, using an approved means of insulation.

Particular attention shall be given to pipework, pump casings, etc. and any part of the plant and equipment likely to stand for periods charged with static water.

Where lagging is used, it shall be suitable for outside installation and completely impervious to all weather and atmospheric conditions on the works. Lagging materials containing asbestos shall not be used.

The lagging shall be sectional and easily removed for maintenance purposes. Joints shall be sealed together with an approved waterproof adhesive tape.

Areas where lagging may be vulnerable to damage shall be suitably protected by an approved means.

302. MATERIALS

302.1 APPLICABILITY

All materials incorporated in the works shall be the most suitable for the duty concerned and shall be new and of first class commercial quality, free from imperfection, and selected for long life and minimum maintenance.

302.1.1 Materials in Contact with Potable Water

Any non-metallic materials such as may be employed for bellows, packing or sleeves, coatings or linings etc. liable to come in contact with potable water shall be approved for the purpose by a recognised approval body.

302.1.2 Materials in Contact with Sewage

Materials in contact with sewage shall be suitable for the environment but particularly all bronze materials shall be true bronze (i.e. zinc free) alloys.

302.2 WROUGHT STEELS

Where not otherwise specified wrought steel shall be selected from the appropriate EN series of BS.970 and be free from blemishes, shot or hammer marks.

The Contractor shall submit for the approval of the Engineer, the EN number selected for the various components.

302.3 CAST MOLYBDENUM STEEL

Cast molybdenum steel shall be supplied to BS 3100.

302.4 CAST IRON

All grey iron castings supplied shall be to the appropriate grade in BS 1452.

All castings are to be free from blowholes, flaws and cracks.

The Contractor shall replace any casting which the Engineer considers is not of first class appearance or in any way is not the best which can be produced, although such a casting may have passed the necessary hydraulic test or other tests. No plugging, filling, welding or "burning on" will be acceptable.

302.5 BRONZE

Where not otherwise specified the bronze used shall be made of a strong and durable mixture of 88:10:2.

302.6 ALUMINIUM AND ALUMINIUM ALLOYS

Castings shall be manufactured from LM5 to BS 1490 and bars and sections from BS 5083 to BS 1490 and bars and sections from BS 5083 to BS 1474 or similar.

Full details of the composition of each alloy shall be supplied to the Engineer for approval, before commencing manufacture.

Immersed structures or structures that are periodically immersed shall not be constructed from aluminium or aluminium alloys.

303. EQUIPMENT

303.1 FLEXIBLE COUPLINGS

Flexible couplings where supplied, shall be generously rated to cover the full range of duty.

Couplings liable to impregnation by oil shall be of the all metal flexible type.

General service couplings shall be of the flexible multi-pin and bush type, having not less than six bushes and each bush shall have an inner sleeve to allow rotation on the pin (bushes shall not be in direct contact with the pin). All pins shall have shoulders to allow positive location and securing to the bosses.

Bosses shall be a tight fit on the shafts and secured with hand fitted keys.

Couplings shall be supplied in matching balanced sets and shall be machined, balanced and marked before leaving manufacturer's works.

303.2 STRAINERS

Strainers shall be flange mounted type. Foot strainers shall be installed at least 0.5 m above the bottom of the water reservoirs.

The strainer basket shall be of the perforated cylinder type made from galvanized steel or stainless steel. It shall be easily accesible via a removable flange.

303.3 GEARBOXES GENERAL REQUIREMENTS

The gearboxes shall be totally enclosed, robustly constructed and suitable for continuous and arduous duty. They shall incorporate ball and/or roller bearings. Taper roller bearings shall be incorporated in the gearbox when thrust loads are to be sustained.

Longlife seals on the input and output shafts shall be fitted up to prevent the escape of lubricant and the ingress of dust, sand and moisture. Breather holes and/or pipes shall be sealed to prevent ingress of lubrican contaminants.

Oil level sight glasses fully protected, shall be provided with levels marked for running and filling, minimum and maximum positions respectively. These shall be arranged for easy viewing. Oil filled caps and oil drain plugs shall be provided.

The design ambient ranges shall be 0° - 50° C.

Lubrication of bearings, etc. shall be by either splash or forced feed system.

The Contractor shall ensure that the lubricant used for the initial filling and specified in the maintenance manual is adequate for prolonged operation in ambient temperatures of up to 55°C without overheating.

Cooling may be by convection from the gearbox casings but without assistance from cooling fins or fans. Adequate other cooling means shall be provided as applicable. The exterior of the gearbox shall be free from dust or moisture traps.

Access for inspection purposes shall be allowed for in the design of the gearbox casing.

Substantial eye bolts shall be provided for all reasonable lifting purposes.

The gearboxes shall carry the manufacturer's identification details together with the rated shaft speeds, output power and maximum ambient temperature.

The gearboxes shall conform to the relevant British Standards with respect to the following requirements :

i) The design ambient shall be 0°C to 50°C.

ii) The noise at 120% of the full output power and 50°C ambient shall not exceed 90 dBA at 1 meter.

iii) The gearing shall give double the life of the bearings if subjected to similar loading.

303.4 SURGE SUPPRESSION EQUIPMENT

Surge suppression equipment may be of one of the following systems:

i) A Hydro-Pneumatic system
ii) A Hydro-Nitrogen system
iii) A Surge Anticipation valve system.

303.4.1 Surge Pressure Vessels

Surge pressure vessels shall be designed and constructed to BS 5500, construction category 1, 2 or 3, post weld heat treated and with a corrosion allowance of 1mm. The vessel shall be cylindrical, carbon steel, fusion welded with domed ends and mounted vertically on steel supports. The vessel shall be provided complete including the following fittings:

- McNeil type access manhole with opening not less than 450 mm x 410 mm;
- Water inlet/outlet branch flanged to BS 4504 Table 16 or 25 as necessary;
- 100 mm dia. drain branch with gunmetal valve and handwheel with drain pipework discharging to drainage channel;
- Spring loaded gunmetal safety valve;
- 100 mm dia. glycerine filled pressure gauge complete with gunmetal isolating cock;
- Air/Nitrogen inlet fitting incorporating a release valve, isolating and non-return valves;
- Access ladder;
- Lifting lugs;
- Nameplate giving vessel details.

The pressure vessel may be constructed with or without a bladder of suitable material and shall withstand the maximum test pressure of the system.

The Hydro-Nitrogen pressure vessel shall be connected to and supplied with a Nitrogen bottle(s) and necessary accessories. The Nitrogen bottle(s) shall be of sufficient volume capable of pressurising the vessel to the working pressure.

303.4.2 Magnetic Level Indicator

The sight glass level indicator shall have the following characteristics:

Temperature operating range: -40°C - 400 °C.
Operating pressure range: Vacuum - Max test pressure.
No requirement for energy source.
Pressure compensated floats to avoid float drowning.
Magnetic coupling of the indicator elements.
An excellent readability ensured by resistance against product contamination and UV rays.
Corrosion resistant.
Highest operational safety through separation of liquid & indicator display.
No re-calibration required.
High mechanical strength.

The level indicator shall be equipped with magnetic switches and a continuous control elements and transmitter allowing remote monitoring of water level alarms and controls.

303.4.3 Air Compressors

The air compressor shall be capable of charging the pressure vessel from full of water in approximately 30 minutes. The compressors shall be air cooled, electrically driven and complete with baseplates.

The compressors are required to deliver completely oil-free air but may be of the air lubricated type with two stage carbon air delivery filters providing complete removal of moisture and oil vapour. Each compressor shall be provided with the following features:

- Outlet pressure gauge.
- Pressure relief valve on each stage of compression.
- Suction filter with high separation capacity and silencer.
- Automatic unloading valve for a no-load start under all conditions
- Non-return valve.
- Protective guard between motor and compressor.
- Oil separator filter (Residual oil content 0.05 ppm).
- Filter and dryer for holding back solid and liquid particles of 5 microns.
- Airtight and automatic drainage system with: pneumatic slides, adjustable frequency and duration and controlled by a remote PLC.

303.4.4 Electric Control Panels

Control equipment to provide fully automatic control of the selected duty compressor from the water level measuring instrument of the surge vessel. A time delay shall be incorporated to prevent operation of the compressor during water level changes under surge conditions and a push button feature shall be provided for manual test of the system. The front side shall have a full width door hinged with a rotating handle and positive closing action. The control panel shall include:

- One lock with a key
- Meters with selector switches, HOURMETER/VOLTMETER/ANMETER.
- One switch START/STOP.
- Status indication ON/OFF/FAULT
- Contractors - (Starter).
- One differential thermal protection.
- Control circuit protection circuit breakers.
- One connection terminal (control and power).
- One PLC.
- The required relays for transmitting safety and system regulating data.
- A three pole isolating switch, with operating handle interlocked with the enclosure door.
- A water level control module.
- A non-latching motor test push-button.
- One selection switch LOCAL/REMOTE/ZERO

303.4.5 Pipework

The pipework shall consist of:

Connection between the ductile iron flanged inlet/outlet of the surge vessel and a flanged tee on the pumping station or wellhead delivery pipework.

Compressed air connection pipe shall be seamless galvanised steel for working pressures greater than 35 bars and copper or galvanised steel for working pressures less than 35 bars. Connection pipes to pressure gauge and air compressor shall have a diameter of 12.5 mm (1/2”). The pipework shall be suitably coated and wrapped.

The pipework shall also include an isolating valve, a pierced swing check valve and all necessary bends and fittings required for the complete installation.

303.4.6 Cabling

Between the switchboard and the control panel
Between the control panel and the compressors
Between the control panel and the level electrodes on the surge vessel
Earthing of all equipment.

303.4.7 Surge Anticipation Valves

The valve shall be installed in a by-pass line immediately downstream of the pump(s) and the check valve. The surge anticipation valve shall be interlocked to the pump(s) via the control valve that shall be supplied with the valve.

The basic valve shall be a single-seated, line-pressure-operated, diaphragm - actuated, pilot controlled globe or angle valve. The valve shall seal by means of a corrosion - resistant seal and resilient, rectangular seat disc. These and other parts shall be replaceable in the field; all such service and adjustments to be possible without removing the valve from the line.

The stem of the basic valve shall be guided top and bottom by integral bushings. The basic valve and its pilot control system shall contain no packing glands nor stuffing boxes.

The diaphragm shall not be used as a seating surface nor shall pistons be used as an operating medium. All internal and external ferrous surfaces shall be coated with a high quality, two-part epoxy primer; the exterior to receive a coat of backed enamel paint.

The pilot control system of the valve shall consist of a controlled pilot-valve, an accumulator, a three-way diaphragm actuated pilot valve, an adjustable needle valve for opening speed control, an adjustable needle valve for closing speed control and a "Y" strainer. To isolate the control system from the main valve, inlet and outlet ball stop valves shall be provided.

- Temperature ratings: 0 ºC - 85 ºC

Maximum pressure differential across the diaphragm of the basic valve must not exceed 20 bars.

Valve materials [Pressure Ratings] : Cast iron - ASTM A126/B [< 25 bars]
Forged or Cast steel - ASTM A126/WCB [> 25 bars]
Cast bronze - ASTM B61, B62 [16 - 35 bars]
Cast aluminium 356 - T6 [< 20 bars]
or equivalent International Standards.

- Stem: Stainless steel/Ductile iron

- Seat Ring: Cast bronze or stainless steel

- Electrical Power:
  AC, 50HZ, in 110/220 volts.
  DC 6, 12, 24, 120, 240 volts.

303.5 LIFTING & HANDLING EQUIPMENT

303.5.1 General

Cranes and hoists shall be of standard proven design in accordance with BS 466, rated for lifting the specified working loads, utilisation and service conditions and shall be suitable for operation from the runway beams provided. Motions shall be motorised as specified with dual speed hoisting facility and controlled from a pendant push button unit via a crane control panel mounted on the gantry.

All operations, wether manual or electric, shall be controlled or performed from motor room floor level unless otherwise specified.

The lifting assembly shall be rated for the highest lift that could occur during installation and maintenance operations, including allowance for stiction.

The crane shall consist of a gantry or jib, crab and hoist assembly, ropes, block and hook together with the necessary running rails and all electrical supply requirements.

Chains used for lifting or travel shall be alloy steel and corrosion protected by an electro-deposited, zinc coated finish after manufacture. They shall not be hot-dip galvanised.

The load chain anchorage, associated fittings and framework at the slack end shall be at least equal in strength to 2.5 times the maximum tension in the load chain when the working load limit is being lifted. Any links used for connecting the load chain to a terminal fitting shall be the material specified for the chain and heat treated to provide mechanical properties and strength equivalent to those of the load chain. the hook shall be made from high grade forged steel complying with BS 2903 "C" type, and provided with a safety catch. The safe working load shall be marked.

Jibs or gantries shall be of plate or box girder design and securely attached to end mountings or carriages.

A reliable braking and locking arrangement shall be incorporated and a load chain collection box shall be incorporated with the crab.

303.5.2 Cross Travel and Long Travel

End carriages for gantries shall be fabricated from rolled steel plates and have two, double-flanged, cast steel wheels to match the track rails. Where rails are supplied and installed under this contract, they shall be adequately supported throughout their length to carry all the dynamic and static loads imposed by the crane duty.

Crab assemblies shall be mounted on four flanged cast steel wheels to suit the jib runway beam or cross-travel rails fixed to the main crane gantry.

Each travel range shall be the maximum permitted by the building and runway constraints. Where applicable the extent of each travel motion shall be limited by electrical limit switches with mechanical end stops secured to the travel rails beyond the electrical limit switch positions, to prevent overrun and building damage from swinging loads mechanical end stops shall also be provided where travel is by manual operation.

In the case of electric motor driven travel two travel speeds shall be provided. The fast speed shall not exceed 16m/min and the slow speed not exceed 4m/min. These drives shall always start at the lower speed and incorporate smooth acceleration and deceleration controls.

303.5.3 Hoist

The hoist unit on travelling beams shall be mounted to provide the highest possible lifting facility whilst maintaining adequate clearance between the crab/hoist assembly and the building structure and fittings.

Hoist units fitted to single runway beams, fixed or jib mounted, shall be of the self-suspension type mounted on a single rigid trolley suitable for manual geared travel along the runway beam. Two end stops shall be provided on the beam suitable for the trolley provided. The trolley shall have ball or roller bearings grease packed for life.

The hook shall be fitted with a swivel and a safety catch and be capable of touching the floor and providing a minimum lifting height as specified.

In the case of electrically operated hoists the normal hoist speed shall be approximately 4 metres/min and the creep speed shall be approximately 600mm/min or nearest standards. An overload device and overwind limit shall be included to prevent dangerous overloads. Raise and lower limit switches shall be provided at the maximum and minimum lift positions. Instantaneous fail safe braking in the event of power failure shall be provided.

Where operation is by electric motor a power supply shall be provided under the contract. Power shall be taken from a feed in the main distribution panel forming part of the works and a wall mounted fused isolator shall be provided at a suitable location approximately 1.5 m above floor level alongside the lifting installation.
Power transmission to the moving installation shell be by pick up shoe running along the underside of shrouded rails, suspended concertina cable running on slides or a rail or a cable from a self winding cable reeling drum . In the latter case the tension in the cable shell be controlled and supports provided to prevent the cable drooping more than one metre below the crame rail (s).

303.5.4 Rating Plates

The SWL shall be clearly marked in Arabic and English language on the rating plate and shall be legible from the plant working level.

303.5.5 Paint Finish

The finish colour shall be a full gloss Yellow Colour No. 356 to BS381C or equivalent reference 08 E 51 to BS 4800.

303.5.6 Crane Access

Where clearances permit, provision for safe access for maintenance shall be provided in accordance with BS 466 and shall include a walkway across the span having a height clearance of 2m and be fitted with double-tiered handrails and toe boards.

An extending, portable aluminium ladder shall be provided for access to the crane for maintenance etc.

303.5.7 Crane Controls

The electrical controls shall be designed to prevent excessive acceleration, retardation, skidding and load swinging and all motions of the crane shall be arranged to be switched through the slower speed where provided.

The control circuits for the crane/hoist shall operate at not more than 110V and be derived from a double wound, screen earthed isolating transformer with one side of the secondary winding connected to neutral/earth. The primary supply shall normally be from the phase conductors.

Fuses shall be provided on each primary and secondary supply and be clearly labelled and segregated. A link shall be fitted in the neutral/earth connection.

303.5.8 Control Panels

The crane control panels shall be constructed of sheet steel or other approved material and shall be hoseproof (IP65).

The control panel shall be mounted on the traveling crane hoist bogie in a convenient position for inspection and maintenance, and shall house all the fuses, motor protection devices, starters and control equipment for controlling the crane/hoist. All contactors shall be of the air-break, electrically operated hold-on type with all necessary auxiliary contacts. Reversing contactors shall be mechanically and electrically interlocked to prevent conflicting operations.

The panel shall be fitted with a main isolating switch interlocked with the door to allow access only when the switch is open.

The motor starters shall be provided with adjustable overload protection devices suitable for the motor load at each speed and having manual resetting facilities within the panel.

All control equipment shall be fitted with suitably rated fuses. Fuse ratings shall be rationalised as far as possible to limit spares. Where practicable, fuses shall be housed in all-insulated carriers with fully shrouded bases.

Fuse links shall be HRC cartridge type to BS 88, Class Q1, having provision for screw fixings for attachment to the carrier.

303.5.9 Pendant Controls

A heavy duty, industrial pattern pendant push-button control station shall be provided, having sets of non-maintained push-buttons for each hoist speed and function specified.

Each set of buttons shall be electrically and mechanically interlocked so that conflicting operations are prevented and only one function can be initiated at one time.

The push-button enclosure shall be of a tough neoprene rubber suitable for withstanding arduous duty and provide full electrical safety, each button being suitably labelled with its function. It shall have an IP55.

The pendant shall be divorced from the crab and capable of independent cross travel. It shall be suitable for vertical adjustment for operation from alternative levels by means of spring loaded reeling drum fitted with a ratchet device or motor driven reeling drum and have a cable guide runner to assist re-coiling.

Pendant control cables shall be designed for reeling drum application and have stranded copper flexible conductors, EPR insulated to 300/500V, multicores laid-up with an internal central textile strain carrier and heavy duty, textile braid reinforced, PCP sheath.

For non-reeling applications, the outer sheath may be flexible PVC, incorporating externally laid, galvanised steel, nylon coated strainer wires.

303.5.10 Radio Control

Where specified, the crane remote control shall be by means of radio transmitter and receiver units operating within the UHF waveband range approved by the relevant authority. The receiver shall be accommodated on the crane in a metal enclosure to IP55, having shock absorbing, rubber mountings, an external receiving aerial and incorporate an output relay for each transmitter function.

The transmitter shall be a lightweight, hand held device enclosed in a heavy duty impact resistant enclosure to IP67 complete with a bandoleer carrying strap.

The unit shall be powered by rechargeable batteries having capacity for 10 hours continuous operation on fully charged batteries. To conserve battery life, a 'time out when not in use' function shall be incorporated and the stop button shall be fitted with a key switch to prevent unauthorised use. All push buttons shall be spring returned to the 'off' position and interlocked to prevent conflicting operations. Programmable security coding shall prevent operation from unwanted signal interference.

A suitable wall mounted, metal enclosed charger shall be provided to enable the transmitter to be connected and maintained in a fully charged condition when not in use.

303.5.11 Flexible Cable Systems

The supply to the crane for both cross travel power together with pendant cross travel connections, shall be by flexible round or flat-form cable systems suspended on trolleys sliding in galvanised track from the crane structure.

The trolleys shall be formed from stainless steel side plates and axles with nylon runners. Sufficient trolleys shall be provided to effect a maximum cable loop of 0.5m.

The cables shall be PVC insulated and flexible PVC sheathed type designed for the application, incorporating flexible stranded copper live and earth conductors, terminated in suitable junction boxes as specified with weatherproof glands designed for the cable shape.

303.5.12 Busbar Collector System

The power supply and earth connection for the long travel shall be from a current collector system of fixed busbar conductors which shall each be fully shrouded with PVC covers suitable for outdoor use.

The conductors shall be suitable for the current capacity, voltage drop and temperature conditions for the installation. Current collectors shall be of the sliding contact type with insulated contact heads mounted on spring loaded trolley arms. No current carrying surfaces shall be exposed.

303.5.13 Cable Reeling Drums

Cable reeling drums shall be of the spring loaded type which coils the cable radially about the drum axis and arranged for direct pulling off the drum, the core diameter being not less than the minimum bending radius of the cable. The springs of the drum shall be adequately rated to reel the useable length of cable fitted with the maximum tension applied shall not exceed the cable makers recommendation. Motor driven reels shall be provided where the spring loading is excessive.

The cable shall not overheat when used with the cable fully retracted. A totally enclosed slip ring connection box suitable for glanding the incoming supply cable, shall be fitted and the slip rings shall be rated to carry the full load current continuously and be accessible for maintenance.

Where specified, anti-condensation heaters shall be provided in the slip-ring enclosure, supplied at 240V AC or less from the appropriate slip rings via a fuse and link which shall be accessible without removal of the slip ring housing.

303.5.14 Trailing Cable

The trailing cable shall be 450/750V grade multicore type, designed to be suitable for use with a reeling drum. The size of the cable shall be such that a maximum recommended tension that may be applied to the cable is not less than the tension produced by the reeling drum.

Conductors shall be of flexible stranded copper, vulcanised rubber insulated with numbered tapes over each core. They shall be formed in a short lay round a flexible non-conducting centre core, sheathed overall with a textile covering and heavy duty PCP sheath.

Cable conductors shall be not less than 2.5mm² and sized so that they will carry the maximum full load working current involved without excessive voltage drop and take account of thermal de-rating in accordance with the IEE Regulations, as applicable to the particular drum and mode of cable winding.

In addition to any supply, control, or motor feed cores, the cable shall contain an earth core of size not less than that of the largest phase conductor.

NB. Cable material descriptions:

PVC Polyvinyl chloride (BS 6746)
EPR Ethylene propylene rubber (BS 6899)
CSP Chlorosulphated polyethylene
PCP Polychloroprene (propylene/chlorosulphated polyethylene)

303.5.15 Rail Bonding

Each section of running rail on the side adjacent to the supply isolator shall be bonded together and the rail connected to the earth terminal on the supply isolator by a protective earth conductor having a conductivity not less than that provided by a 4mm^2 section copper cable. The rail bonds shall be made by either of the following methods:-

i) Each section of rail is to be drilled near its end with a 7mm (9/32") hole.

An 8 SWG steel wire bond, galvanised to grade GLS400 to BS 182, is to be connected across each joint and secured at each end into the hole in the rail section by means of a tinned tapered steel pin which has a semi-circular groove along its length to hold the wire. The wire is to be overlength and the excess taken up by forming the wire into a 'Z' shape to absorb the expansion.

ii) For indoor locations, an overlength, 4mm^2 section of tinned copper braid, fitted with crimped lugs at each end shall be bolted to each rail end by means of brass bolts and washers of not less than 6mm dia.

303.6 ENCLOSURES

303.6.1 Definitions

The generic term enclosures shall be taken to mean any housing which encloses overall any items of plant or equipment. To distinguish between the different forms of enclosure, the following definitions shall be used.

a) Cabinets will be regarded as any wall or pedestal mounted, thermally controlled enclosure.

b) Kiosks shall mean any floor standing, thermally controlled, overall enclosure which may incorporate either an integral base or use the ground or floor slab as the base of the enclosure. The Kiosk shall be sized to permit man access for servicing the equipment within.

c) Shelters shall mean overall floor standing housing providing general weather protection without sealing or thermal control.

d) Housing shall mean the specific enclosure without thermal control for items of equipment, either located externally or within another enclosure.

e) Compounds shall mean areas enclosed by fencing or walls but generally exposed to the weather.

303.6.2 General

All cabinets and kiosks shall be fully weatherproof enclosures to IP 55, manufactured from maintenance-free, resin bonded, glass fiber reinforced, polyester (GRP) inner and outer skins, encapsulating not less than 12mm plywood reinforcement and insulation to give a `u' value of at least 1.5W/m²°C. The doors shall have flexible neoprene seals.

All cabinets, kiosks and shelters shall have doors incorporating steel reinforcement for rigidity and self-locking stays to maintain the doors open to at least 90°.

Door hinges shall be black epoxy coated, vandal-proof pattern with stainless steel pins. Locking door handles shall also be black epoxy coated steel with stainless steel cam action locking plates.

Where double doors are provided, shoot bolts shall be fitted to the top and bottom of the left hand door, central dead-locking of latch to right hand door to incorporate a security keyed `Yale' type lock to suit local key or other specified standards.

The closing edges of the doors shall have an external or internal overlap for weather sealing.

Ventilation to kiosks and shelters shall be provided either as under-eaves or via high level louvered vents protected by a fine mesh stainless steel/aluminium insect screen. Ventilation provided shall be equivalent to a 10mm continuous gap around the enclosure perimeter.

The interior shall be finished with a white based abrasion resistant vinyl paint. The exterior finish shall be GRP coloured Dark Green to BS 4800 (14 C 39) unless otherwise specified.

303.6.3 Cabinets

Wall mounted equipment cabinets shall have external fixing lugs and have removable gland plates fitted to the base for cable or pipework entry.

All cabinets shall have mounting rails bonded to the rear wall to facilitate equipment fixing and have an anti-condensation heater fitted. Outdoor mounted cabinets shall have a rear sloping top and a 50mm projecting drip canopy above the access door.

Inspection windows of toughened glass secured in a rubber gasket shall be provided where specified.

303.6.4 Kiosks

Where control panels are to be protected in outdoor locations they shall be enclosed in a cross ventilated weatherproof kiosk, sized to allow at least 1.0m clear working space in front of the panel. Battens shall be moulded to the inside walls to provide fixings for internal equipment and fittings.

The kiosk materials shall have a ½ hr fire resistance rating for retention of stability, integrity and insulation in accordance with BS 476 Pt 8.

Sectional kiosks shall be pre-assembled and fully sealed before delivery to site.

Fixing holes shall be provided in the base sections and the whole unit shall be fixed and sealed to the concrete base by means of a mastic compound applied before and after the kiosk sections are in place, to prevent ingress of moisture.

Kiosks shall be fitted with:

a) A suitable corrosion proof fluorescent light fitting, not less than 60 watt, so arranged to illuminate the face of the control panel complete with MK `Seal' On/Off switch inside the kiosk, wall mounted adjacent to the kiosk door, and wiring.

b) A suitably rated anti-condensation heater complete with thermostat, On/Off switch and wiring.

All electrical fittings to be connected by wiring in surface mounted PVC conduit to a 2 way metalclad consumer unit.

When space for the Electricity Supply Authority metering equipment and cut-outs is specified, a separate section within the main frame of the kiosk is to be provided complete with fire resistant chipboard panel. Details of size required and position in relation to the panel are to be obtained from the appropriate Electricity Supply Authority. Where specified, a lockable hinged door shall be provided to enable the meters to be read from outside the kiosk.

Where an external generator connection as specified, a small door or `cat-flap' shall be fitted opposite the panel mounted appliance inlet to provide access for a generator cable and connector. The door shall be large enough to pass the connector and it shall be horizontally hinged at the top, outward opening and lockable with a suitable padlock.

303.6.5 Shelters

Protection for plant requiring limited attention shall be of maintenance free materials, single skin GRP insulated panels or hot dipped galvanised steel panels with plastic skin external coating and alkyd paint interior. The shelter shall provide a degree of protection to IP44.

303.6.6 Housing

Field mounted electrical components and junction boxes shall be heavy duty industrial type, accommodated in totally enclosed hoseproof housings to IP65, of die cast, cast aluminium or rigid non-ferrous/polycarbonate materials having tapped conduit entries and recessed neoprene gaskets to seal the covers, the cover and housing fixings being outside the sealed area of the box.

303.7 COMPRESSORS/BLOWERS

303.7.1 Compressors

303.7.1.1 Air Compressors

Air compressors shall be air cooled capable of oil and dust free air delivery at the volume and pressures specified when directly or indirectly driven by an electric motor.

The compressor performance shall be in accordance with BS 1571 for the site condition and duty cycle specified and shall include the following components:

a) Suction air filter/silencer

b) Solenoid operated unloader valve

c) Pressure relief valve

d) Non-return valve

e) Isolating valve

f) Low oil pressure switch (if pressure lubricated)

g) Pressure gauge

h) Emergency stop push button

The equipment shall be suitable for operating in the climatic conditions detailed in the tender documents.

Where necessary, depending on load factor, the compressor shall include cylinder jacket and after cooler facilities for cooling the delivered air, the aftercooler having a suitable pressure relief valve and automatic drain valve.

303.7.1.2 Air Receivers

Air compressors shall deliver air into an air receiver manufactured in accordance with BS 5169 Class III Grade E or F, to accommodate the specified design pressure and internal volume.

Receivers shall incorporate the following items:-

a) One safety relief valve.

b) One automatic drain valve.

c) One pressure gauge (0 - bar).

d) Pressure and temperature switches to suit the control.

e) Inspection access to permit internal examination of the receiver.

f) Lifting facilities as determined by the receiver weight.

Receivers shall preferably be located in low ambient temperature areas to minimise condensation and the inlet and outlet pipe connections shall be arranged to promote air circulation.

303.7.1.3 Separators

The air distribution main shall include a separator designed to remove suspended moisture in the air main.

303.7.1.4 Compressed Air Filters

The air supply shall incorporate filters of the disposable element type as near as possible to the point of use.

Filtration shall be carried out using two filters in series, the first filter graded for course filtration and the second for fine filtration as defined in the Specific Requirements.

303.7.1.5 Drain Traps/Strainers

Automatic drain traps shall be provided for air receivers, filters and separators. Strainers shall be provided for protection of the drain traps. Ball traps shall have cast iron bodies with stainless steel internal parts (Spirax Sarco or equal).

303.7.1.6 Air Pressure Control

The compressor shall be arranged to maintain the air pressure in the system within the specified limits by means of pressure switches in conjunction with unloader valves and timers to prevent prolonged off-load running.

The frequency of starting and stopping shall be within the limitations of the drive arrangement.

Where two compressors are operated on a duty/standby basis, the duty compressor shall operate whenever the low pressure switch closes and shall cease operation when the high pressure switch opens. Should the pressure fall to the standby low pressure, the standby compressor shall operate in conjunction with the duty compressor and shall similarly cease operation when the high pressure switch opens.

The circuits for the compressor motor starters shall be completely separate. Either unit shall be capable of duty or standby operation and periodically their modes will be reversed.

303.7.2 Blowers

303.7.2.1 Air blowers

Blowers shall discharge continuously the specified free air delivery at specified suction and delivery pressures. They shall be suitable for automatic operation in all aspects.

Blowers shall be of the centrifugal or positive displacement rotary type capable of delivering oil-free air with high grade cast iron casings adequately ribbed to avoid distortion. The blower shall be fitted with mechanical seals and incorporate a mechanical oil lubrication system, including an oil flow indicator, level indicator, pressure gauge, filling and drain plugs.

The design of the blowers is to be such that the noise level is to be kept to a minimum.

The impellers shall have accurate contour. Impeller and shaft shall be made from one casting. Impellers shall be statically and dynamically balanced.

Impellers shall each be equipped with heavy duty spherical roller bearings at each end. Gear end bearings shall be axially located on the inner and outer races to control thrust and maintain factory set clearances at all times. Adequate facilities shall be made for the inspection of the rotors.

The two timing gears shall be of nickel cast iron or other approved material, accurately machined to position the impellers in the impeller case and shall be secured to the shafts by locking kits. Gears shall be enclosed in an oil-tight housing.

The shaft sealing arrangement shall comprise a garter spring viton lip seal and a piston ring seal with an intermediate space vented to atmosphere.

Gears and gear end bearings shall be lubricated by a splash oiling system from oil maintained in the gear housing. Drive end bearings shall be grease lubricated or lubricated by a splash oiling system from oil maintained in the drive cover, depending upon gear size.

Each blower is to be direct driven through a flexible coupling, or indirectly via `V' belts, by means of an electric motor, the complete assembly being mounted on a cast iron combination or fabricated steel base plate. Anti-vibration mountings and flexible pipe joints shall be provided. Both driver and driven units are to be dowelled or otherwise positively located to the base plate and substantial guards provided over all moving parts.

All covers and flanges associated with spigotted joints should be provided with easing screws if possible.

In view of high discharge air temperature, the Contractor shall install a protective barrier around all pipe work below 2.5m above blower room floor level.

303.7.2.2 Blower Accessories

Each blower shall include a tachometer, an adjustable weight operated lever type air relief valve, delivery pressure and suction gauges each with isolating cocks mounted on a panel secured to the blower. An automatic unloader vented to outside atmosphere or an approved by-pass system is also to be included if this will assist in starting.

The air relief valve is to be of double flanged cast iron construction with gunmetal trim. The adjustable weight shall have provision for locking to prevent any unauthorised interference.

Bosses shall be provided on each blower discharge pipe, upstream of the non-return valves, suitably tapped for connection by capillary tubing to pressure switches.

303.7.2.3 Blower Filters

The filters shall be capable of handling the designed throughput of air with the minimum of pressure drop whilst excluding 99.7% of all particles down to 2 microns.

The filters shall be of the two stage type comprising a hand operated roller mounted first stage roll type element and a disposable cartridge type second stage having access from one side only. The first stage unit is to be mounted in a galvanised sheet steel case with easily removable covers, the roller handle being conveniently positioned for easy adjustment of the roll. The second stage unit is to be mounted in a galvanised sheet steel case and the units connected by a transition piece, a further transition piece being arranged between the second stage and the silencer. Connections with isolation taps are to be provided on both sides of each stage and suitable manometers fitted to allow for measurement of the differential pressure.

Where required the suction of each blower shall incorporate an "in-line" air filter and silencer. The air filter shall be of the replaceable paper element type and shall be fitted with a differential pressure gauge with adjustable alarm contacts to initiate an alarm in the control panel on high differential pressure across the filter.

Each unit shall be supported from the floor on substantial steel frames with welded plate feet.

303.7.2.4 Air Silencers

Single inlet and outlet silencers shall be included for the blowers and manufactured of sheet steel, comprising a perforated inner tube and an outer galvanised casing, the space between being filled with a sound absorbing material. A flange is to be provided at each end, and all necessary supports extending to floor level are to be included. The silencers are to be designed for the minimum pressure drop.

303.7.2.5 Lifting and Handling

Blower units shall incorporate lifting eye bolts for ease of handling and installation/Removal.

303.7.2.6 Method of Control

Both manual and automatic control shall be provided for the blowers. A "hand-off-auto" selector switch shall be provided in the motor control and distribution panel.

In auto mode, the standby blower will alternate to duty position every 24 hours of operation.

303.8 DIESEL ENGINES

303.8.1 General

The engine shall be a cold starting 4 stroke water cooled, multi-cylinder in-line or "V" form, naturally aspirated or turbocharged and intercooled, totally enclosed industrial diesel of standard proven design, designed to run on liquid petroleum fuel to BS 2869 Class `A' and incorporate all starting, lubricating, cooling, monitoring, alarm and shut-down systems suitable for automatic and continuous unattended operation.

The engine crankcase shall be fitted with a breather pipe and safety devices to provide protection in the event of an explosion.

Crankcase access panels shall be provided for maintenance/inspection where possible.

Each engine shall be designed to operate with an ambient air temperature of 50°C and be capable of satisfactorily providing an output 10% percent in excess of the BS rating at the same speed for one hour in any period of 12 hours consecutive running.

All electric motors provided for ancillary equipment associated with the electric generation plant shall be of the squirrel cage type protected to IP55.

303.8.2 Duty and Rating

The engine shall be rated in accordance with BS 5514 to provide the necessary torque and power output at a rated speed not greater than 1500 rpm, to drive the specified load under the given site conditions.

303.8.3 Flywheel

The engine crankshaft shall be fitted with a flywheel of suitable inertia to absorb speed variation to within the specified limits. The flywheel shall incorporate all necessary barring facilities and timing marks. Safety devices shall be fitted to prevent the engine starting when any barring gear is in use.

The crankshaft shall be of solid forged steel statically and dynamically balanced to very close limits.

Hand operated barring gear shall be provided for each engine.

303.8.4 Torsional and Cyclic Characteristics

The rotating system of the engine and ancillaries shall be statically and dynamically balanced during manufacture. Detachable components eg. fans shall either be separately balanced or permanently marked in a manner that ensures correct angular positioning.

For alternator drives, the coupling between the engine and alternator shall be a flexible type of the manufacturer's standard arrangement and the torsional characteristics, cyclic irregularity, angular deviation and freedom from resonance shall comply with BS 4999, Part 142 and BS 5514 Part 5. The interchange of information between the engine and alternator manufacturers as directed therein shall be observed so as to ensure this.

303.8.5 Governor and Speed Control

The engine shall be fitted with a governor suitable for automatically controlling the engine speed in accordance with class 2 of BS 5514, Part 4. Provision shall be made for variable hand speed control, emergency manual shutdown and an over-speed trip arranged to cut-off the fuel supply.

Motor operated speed regulating gear shall be provided to enable the speed of the engine to be varied by 5% percent up or down from normal speed while in operation. The remote control for this regulating gear is to be operated from the switchboard.

303.8.6 Overspeed Protection

Overspeed protection shall be provided so that in the event of the engine speed exceeding 10% percent above the maximum operating speed an audible warning and indicator light shall be brought into operation, but should be speed still continue to rise to a figure of 15% percent above normal speed the fuel supply shall be automatically cut off and the engine brought to rest. The audible warning and indicator light, together with the other indicating lights and alarms specified hereafter, shall indicate on the monitoring panel in the alternator switchboard.

303.8.7 Air Intake

The combustion air for the engine shall be drawn from the area specified, through an air filter having elements of a type commonly available.

Where combustion air is ducted from outside the building, the duct entry shall be fitted with a coarse mesh and fixed louvres arranged to prevent the entry of debris, small animals and the products of inclement weather.

303.8.8 Fuel Systems

The engine fuel system shall consist of an engine mounted daily service tank, filters and fuel injection equipment with solenoid operated fuel cut-off valve, a gear driven mechanical high pressure fuel pump and isolating valves for the fuel supply to and from the service tank, all mounted adjacent to the engine.

Fuel leak off shall be piped back to the fuel filter assembly or the daily service tank. The high pressure fuel lines between the pump and injectors shall be sheathed to contain and return any spillage to the daily service tank. Such return pipework shall incorporate a reservoir chamber with a float switch to detect any accumulated leakage. Fuel atomisers shall be easily removable and interchangeable.

All fuel pipework on the engine shall be rigid tubing neatly dressed and clipped to avoid vibration or interference with maintenance procedures, have simple facilities for the relief of air locks and be spaced at least 50mm clear of any surfaces whose temperature exceeds 200°C.

Fuel filters shall be full flow type fitted with re-usable mesh material. For continuously running, base load applications, filters shall be twin or triple compartment type with a change-over cock to enable one cartridge to be removed for cleaning without stopping the engine.

303.8.9 Lubricating System

The lubrication system shall permit automatic starting of the engine and immediate load acceptance and consist of a wet sump with integral engine driven gear type pump providing forced lubrication to working parts through an oil cooler and a duplex full flow filter. The filter shall use disposable elements commonly available and be of adequate capacity to allow continuous periods of running without changing or cleaning.

Independent electric motor driven engine lubricating/pre-heating units shall be provided to give automatic periodic priming in accordance with the manufacturer's recommendation while the engine is at rest.

A hand priming pump shall also be fitted to enable all parts of the engine to be lubricated as required.

The cooling of lubricating oil on engines with engine mounted radiators may be by an `oil' section in the radiator. Engines with remote mounted radiators shall be provided with engine mounted water-to-oil heat exchangers for the cooling of lubricating oil.

The engine shall employ thermostatically controlled, liquid cooling using fresh water in a closed circuit, designed to suit the ambient conditions specified and comprise an engine driven circulating pump and a self-venting radiator. The pump shall also be capable of circulating sufficient coolant through the engine's lubricating oil cooler. Facilities for topping up and draining the system shall be provided together with a thermostat with a warming up by-pass.

Protected thermometers in suitable pockets shall be provided for measuring the temperature of the inlet and outlet cooling water and lubricating oil.

In addition to the overspeed alarm, protection devices shall be provided in the lubricating oil circuits and cooling water circuits to operate alarms and indicator lights, in the event of abnormal running conditions prevailing. These lights shall indicate on the remote monitoring panel. The engine shall shut down under alarm conditions.

A make-up header tank and automatic float valve shall be provided, together with all necessary connections to the specified supply source and the cooling system.

The cooling water shall include a quantity of anti-freeze to give protection to minus 10 degrees centigrade. An immersion heater and control thermostat shall be fitted to the system within the engine block to protect the coolant from freezing and shall operate from a 220V AC supply when the engine is not running.

Radiators mounted on engines shall be cooled by a `pusher' type engine driven fan which draws air from the vicinity of the engine block and discharges it through the radiator core. They shall also include a suitable mounting flange for the attachment of air duct trunking.

Remotely mounted radiators shall be cooled by an electric motor driven fan fed from an auxiliary generator directly driven by the engine.

If the engine cannot be fitted with a suitable direct driven coolant circulating pump capable of maintaining adequate circulation through a remote radiator, an auxiliary electric motor driven pump shall be provided. This pump shall be arranged to operate from the same supply serving the electric motor driven radiator fan.

303.8.10 Engine Cooling Equipment

Each engine shall be cooled by a bedplate mounted tropical rated radiator and cooling fan, adequately rated to maintain the normal working temperature, under continous, full load operation, working in conjunction with a pressurised water system, thermostatically controlled with centrifugal water circulating pump, valves and pipeworks.

303.8.11 Exhaust System

Each engine shall be fitted with a suitable exhaust system from the engine to the specified discharge point. The route shall be as short as site conditions allow and minimise the number of bends, which must be of large radius. The system shall include a primary residential type silencer, flexible and rigid pipework, roof cowl, flashing and all necessary ties and supports. The primary silencer shall be supported from the engine set and shall have a flanged outlet incorporating a flexible stainless steel bellows section for ease of disconnection from the remainder of the exhaust system. The exhaust system shall be insulated with a non-asbestos material. Removable cladding shall be provided on the exhaust system where specified.

Support brackets shall allow for pipe expansion and where the pipe passes through walls, a sleeve or wall plate shall be fitted with an adequate hole clearance to prevent wall damage or fire hazard. Pipe flanges shall be fitted on each side of the wall.

The interior of the pipework and silencers shall be metallic aluminium spray coated to BS 2569 Part 2 Class `D'. Where insulation is not applied, the exterior shall be similarly coated and shall be finished with a coat of high temperature aluminium paint from an approved manufacturer.

303.8.12 Fuel Oil System

A complete fuel oil systems including bulk storage and daily service tanks and transfer pumps shall be provided. It shall comprise steel, domed end horizontal cylindrical bulk storage tanks. Each tank shall be mounted on prepared foundations, and shall be complete with manholes, filling and draw-off connections, vent pipes and inspections holes an externally indicating contents gages. The necessary access ladder and platforms over the tanks shall also be supplied.

There shall be no gravity feed from bulk fuel tanks to service tanks, and no possibility of promonting and maintaining siphoning through fuel transfer pumps. All necessary valves shall be included to ensure this. Service tank overflows shall be carried back to the bulk fuel storage to avoid any flooding of the engine room with fuel oil.

Arrangement drawings shall be supplied to illustrates the complete fuel supply system showing the position of tanks, valves, pumps and all other related equipment.

A single line scheme diagram of the system shall be submitted and of a form suitable for permanent display in the generator building.

An accurate fuel oil meter shall be inserted in each feed from the daily service tanks to the engines. These meters shall be in such a position to be readily readable.

Two filters shall be provided in the main fuel oil supply line with by-passes enabling one filter to be taken out and cleaned without interrupting the supply of oil through the other filter.

The whole of the fuel system including bulk tanks and daily service tanks shall comply with the requirements of painting and metal protection, finished colour as instructed by the Engineer.

A) BULK FUEL TANKS

A bulk fuel storage tank shall be provided or alternatively 2 tanks to provide the required storage volume and shall be manufactured and arranged with all ancillary apparatus to fit within the areas allocated on the Drawings. The size of tank(s) shall be such as to contain a sufficient quantity of fuel oil for operation at full load continuously as specified in the particular specifications.

The tank(s) shall be constructed of not less than 3 mm thick (nominal) plate which shall be free from imperfections and constructed as a rigid unit with internal partitions or bracing if necessary. The contractor shall submit for approval the calculation note justifying the selection of the final thickness to be adopted. The tank(s), or where it has more than one compartment, each compartment, shall be provided with a manhole and provision for ventilation to a single point shall be made.

All seams shall be continuously welded from both sides. Provisions shall be made to prevent damage to the tank bottom by impact from the dip-stick. For this purpose a welded stop collar shall be provided at the top of the dip-stick to rest on the manhole cover.

The dip-stick shall be of non-ferrous material accurately calibrated and clearly marked so as to be readily identifiable with its respective tank and shall be supplied, calibrated in liters, by the tank manufacturer.

The dip-stick tube shall be incorporated in the manhole cover, no separate tank opening being provided for this purpose.

Each tank shall be arranged for filling via a direct filling pipe which shall be positioned to give easy access for the delivery tanker. A minimum of 5% percent by volume of the tanks contents shall be allowed as ullage.

The filling pipe and dip-stick tube shall each have a liquid and vapour-proof screwed cap with captive chain and fitted with a lock with four keys.

The filling pipe and dipping tube shall be carried down to within 50 mm. of the tank bottom. The suction and return flow pipes shall terminate not less than 25 mm. above the bottom of the filling and dipping pipe so as to maintain a liquid seal.

A vent pipe not less than 75 mm. diameter shall be fitted to the highest point of the tank, and shall terminate with a wire cage for protective purposes (fine gauge shall not be used).

Each storage tank manhole shall be in an accessible positition and shall not be less than 600 mm. diameter clear opening. The manhole lid shall be securely fixed by bolts and have a liquid and vapour tight joint (close woven proofed asbestos graphited).

The outlet pipe shall be so arrange as to leave a minimum of dead space in bottom of the tank.

Each tank shall have connections to receive the excess flow from daily tank overflow.

Each tank shall also be provided with an externally indicating contents gauge marked in Arabic and English to read "full - 1/2 full - empty with intermediate tenths marking.

All openings shall be closed with steel plugs and blanking off steel plates bolted to flanges for transit to site.

The Contractor shall provide all details of his requirements for access holes, etc. required to the storage tanks to enable the constructive of the tank installations generally to the arrangement shown on the Contract drawings.

Bulk storage tanks shall have the internal and external surfaces descaled by grit blasting, pickling or other approved method. After descaling, external surfaces shall be given a phosphate coating followed by a cold water washdown. External surfaces shall be painted as specified. The interior shall immediately be oiled.

B) DAILY STORAGE TANKS

Each engine shall be provided with a free standing daily tank of sufficient capacity to allow 24 hours of continuous operation at full load and shall be provided with the following fittings :

i- Air vent of not less than 50 mm diameter.

ii- Overflow piping of not less than 150% percent diameter of the fuel delivery line.

iii- Cleaning handhole and cover of not less than 300 mm diameter.

iv- Contents gauge graduated in Arabic and English to read "Full - 1/2 ful - empty". The gauge shall be of the magnetically operated type and shall be complete with low and high level control contracts.

v- Outlet connection to engine not less than 50 mm above tank base.

vi- Fuel outlet isolating valve lockable in open position.

vii- Drain plug.

viii-Excess fuel return connection if necessary.

ix- Inlet connection from bulk fuel supply system including pipework and connections.

There shall be allowed a minimum of 10% percent of the volume of the tank contents as ullage. The top oil level of the tank shall not be less than 75 mm from the top of the tank.

Tanks prior to despatch from manufacturers works shall be tested hydraulically to a pressure 0.5 bars.

Daily tanks shall be complete with all supports and fixing bolts for mounting remote from engine base or skid mounted tanks will not be accepted.

There shall be provided all necessary fuel oil pipework, unions and valves between the day tank and the engine.

Fuel connecting pipework to engine shall be seamless steel and all pipes shall incorporate flexible section, if not less than 250 mm long (plastic pipes or fittings are not acceptable).

C) FUEL TRANSFER PUMPS

Adjacent to each daily service tank there shall be provided an electrically driven fuel transfer pump operating in conjunction with the control switches fitted to the daily tank contents gauge. The pump shall be of the positive displacement type rated at a capacity to enable the associated daily tank to be completely filled from empty within 2 hours. The pump motor shall be in accordance with section four and suitable for 380 volts, 3-phase, 60 Hz operation. Automatic control shall be provided for each pump, via the control contacts fitted to the associated fuel contents gauge, to maintain a minimum of 24 hours fuel storage in the daily tank. A semi-rotary, hand operated pump shall be installed and connected in parallel with each electric pump. Both pumps shall be completed with a minimum of 4 m of flexible nose and a two position hand valve to enable the pumps to extract from the bulk fuel tank or, if necessary from a portable drum situated adjacent to the daily service tank.

D) WARNING AND SAFETY DEVICES

The following warning notice shall be supplied and fixed in a prominent position in the vicinity of each bulk fuel tank with 50 mm plain block black letters on a yellow background, printed in Arabic and English.

NO SMOKING

DIESEL FUEL - HIGHLY INFLAMMABLE

Additional notices shall be provided in accordance with the labels signs and notices requirements. The wording of the notices shall be subject to the Engineer's approval.

303.8.13 Fire Cut-off Valves

Fire cut-off valves shall be incorporated in the fuel delivery pipe to each engine from the daily service tank and be located in an accessible horizontal position, coil uppermost, close to the tank.

The valves shall be manually operated and solenoid maintained in accordance with BS 799 Part 7, the solenoid will be arranged to release in the event of a fire signal. The emergency handle shall be labelled with a conspicuous permanent notice reading:

"FIRE VALVE-PULL LEVER DOWN TO ISOLATE FUEL SUPPLY.
LIFT TO RESET".

Where specified, a dump valve shall be fitted in the pipeline immediately beneath the daily service tank so that the tank contents can be returned by gravity head to the bulk storage tank or a suitable external dump tank in the event of a fire signal. Electrically operated valves shall open when the operating solenoid is de-energised.

Fire detection devices shall be installed in suitable locations for alarm and signalling.

303.8.14 Engine Starting

The engine shall be arranged for automatic starting and stopping arranged in conjunction with the overall control system. The engines shall not require pre-start priming of lubrication and shall be arranged for instant starting by batteries or compressed air as specified, the starter motor(s) engaging with the flywheel ring gear and disengaging automatically when the engine starts. The system when fully charged, shall have sufficient capacity to crank the engine when cold, for at least 10 consecutive 15 second periods at 20°C. A self contained charging system shall be provided to meet these requirements.

Batteries shall be of the heavy duty, 24 volt, lead acid type complete with charger, housing cabinet and necessary interconnecting cable.

Each battery charger shall be connected to the main motor control center board in the control room.

303.8.15 Engine Instruments

An instrument panel shall be resiliently mounted on the engine complete with the necessary piping, connections, isolating cocks and indicators for the following:-

- Cooling water temperature
- Lubricating oil temperature
- Lubricating oil pressure
- Revolutions per minute
- Exhaust temperature at each cylinder outlet
- Running hours totaliser (showing 5 digits & non-resettable).
- All instruments shall be scaled in approved metric units and gauges shall comply with C1 5.1.3 - Indicator gauges.

303.8.16 Engine Protection

The engine shall be provided with alarm and shutdown features as specified in Volume 3, Part 4 - Electrical Works. Shutdown conditions shall be arranged to operate through the fuel solenoid.

A manual fuel rack release knob shall be provided for emergency use.

303.8.17 Engine Wiring

All wiring for engine mounted electrical components shall be carried out in suitably rated heat and oil resistant cabling fixed to the equipment where necessary and terminated in a wiring terminal box or boxes mounted in an accessible position on the bedplate, suitable for the necessary cabling to be extended to the local control panel. Separate boxes shall be provided for AC and DC circuits.

For full details of terminal boxes and auxiliary switches see Volume 3, Part 4 - Electrical Works.

303.8.18 Engine Mounting Arrangement

Engine driven sets shall be either close coupled or open coupled as specified, via a flexible coupling. The driven unit shall have two independent bearings and all major items of the rotating assembly shall be dowelled to preserve alignment.

Close coupled sets shall be secured through anti-vibration mounts to a substantial fabricated steel base fixed to the floor.

Open coupled sets shall be fixed to a substantial fabricated steel base frame, secured direct to the floor, or where specified, secured through anti-vibration mounts between the base frame and floor.

The base frame shall be structurally designed and constructed to ensure maximum strength and may be used to mount engine ancillaries, set wiring marshalling boxes and control panels. The frame shall include jacking facilities where anti-vibration mountings are used. These shall not project to cause hazards to operating personnel.

Anti-vibration mountings shall be multiple neoprene bonded pattern, arranged to distribute without resonance the total weight and dynamic loads of the assembled engine set and auxiliaries supported on the base frame.

303.8.19 Drip Tray

A drip tray, complete with drainage cock, shall be fitted within the confines of the baseframe and shall have a capacity at least equal to that of the lubricating oil contained in the engine.

303.8.20 Noise Attenuating Enclosure

The enclosure shall be removable pre-fabricated type designed to reduce the noise level by approximately 20 dB(A).

The enclosure shall incorporate access doors or panels such that routine maintenance can be carried out without removing the entire enclosure. It shall be possible to remove the enclosure without disconnection of the silencer mounted outside the enclosure. The operating sound pressure level of the set, measured in accordance with BS 4196 at a distance of 3 metres, with the exhaust silencer and the noise attenuating enclosure in position, shall be as elsewere specified.

The Tenderer shall state**,** the predicted sound pressure level of the plant under the specified operating conditions, with and without the noise attenuating enclosure fitted.

303.8.21 Ventilation Equipment

Each of the generator rooms shall be provided with fixed, sand-trap type, inlet louvres to allow passage of cooling and aspiration air necessary, during the generator operating periods. Inlet louvres will be supplied and fitted by the civil Contractor. However, the Contractor shall provide and install for each generator set an automatically operated, cooling air exhaust louvre complete with flexible ducting for connection between the radiator and louvre flange. Each louvre shall provide a weather proof seal during non-operating periods and arranged to automatically open on generator start-up, each louvre shall be supplied complete with a matching "bird-guard" wire mesh frame for installation on the exterior wall of the generator room.

Louvres and bird-guards shall be manufactured from aluminium and the Contractor shall advise the size of clear opening required for the extract louvre and confirm the sizes of inlet louvres for the required duty. The ambiant temperature of the generator rooms shall not exceed 40 °C.

303.8.22 Steelworks

The following steelwork shall be provided and fixed in accordance with metal protection and painting requirements.

i- Support frames and access platforms for fuel storage tanks.

ii- All necessary pipe supports.

iii- All ancillary brackets, clamps, etc.

303.8.23 Pipework

All fuel pipes and fittings shall be of seamless stainless steel, all valves shall be cast steel, and designed for the duty they are required to perform. Galvanized pipework and fittings shall not be used for any line handling fuel. All pipeworks shall be fully supported and complete with all brackets and fixings.

Pipework installations shall be carried out for the various items of plant, equipment and shall include : -

i- All pipework and valves from the bulk storage tanks to the daily storage tanks and filling point.

ii- For the bulk storage tanks.

1 No. easily cleaned filter.

2 No. shut off hand operated valves (one each side of filter).

iii- The main fuel line from the bulk storage tank installation shall be fitted with fail safe quick closing emergency valve with replaceable fusible link arrangement to shut fuel off in event of fire. The operating temperature of the heat sensitivity element shall be 93°C.

iv- One complete set valves for each set of fuel transfer pumps comprising suction and delivery isolating valves, non-return valves and pressure relief valve with return pipe.

v- Overflow pipework and fittings from each daily tank to the bulk storage tanks.

The pipework installation shall comply with the general protection requirements. Finish colour shall be as instructed by the Engineer.

303.8.24 Stop Push Button Stations

Local "Emergency Stop" push button stations shall be provided.

Each generator set shall be provided with 1 No. emergency stop push button station, suitably positioned at the end of the generator set assembly.

303.9 FLUMES

Flume formers shall be provided for construction of concrete flumes by the Civil Contractor. The liners shall be a matched pair and a locating jig shall be included to ensure correct installation in the channel. The liners shall conform to BS 3680: Part 4C: 19/4. (Level shall be measured by an ultrasonic measuring system, the detector head to be mounted over the channel. The requirements for ultrasonic level detectors are specified separately.)

303.10 WEIRS (VEE NOTCH OR STRAIGHT WEIR)

Weir plates shall be manufactured from stainless steel or non-ferrous material suitable for the liquid being measured. The weir plate shall be mounted on a fabricated mild steel plate for fixing into the weir chamber. The mounting plate shall be sealed where it fits into the chamber and against the weir plate. The weir plate fixings shall be slotted to allow adjustment on site.

The weir and Vee-notch weir plates shall comply with BS 3680: Part 4A.

Thin plate weirs will only be used on sediment free water.

304. PUMPS

304.1 GENERAL REQUIREMENTS

304.1.1 Materials

Materials of construction of pumps shall be in compliance with the following requirements unless otherwise specified in the Particular Specifications. Other materials of superior quality may be used subject to the approval of the Engineer.

TYPE OF USE	RAW WATER	DRINKING WATER	SEWAGE	HYDROCARBON	DRAINAGE
CASING	NI-RESIST	CAST IRON EPOXY COATED (150 µ) OR SS 316L	CAST IRON	STEEL	CAST IRON
IMPELLER	NI-RESIST	ZINC FREE BRONZE (MAX 3% ZINC)	CAST IRON	STEEL	CAST IRON
TRIM	NI-RESIST 316 L	ZINC FREE BRONZE (MAX 3% ZINC)	CAST IRON	CAST IRON 13 CR	CAST IRON
MECH.SEAL	MANUFACTURER STANDARD	MANUFACTURER STANDARD	MANUFACTURER STANDARD	MANUFACTURER STANDARD	MANUFACTURER STANDARD
STUDS	ASTM A193 GRADE B7	ASTM A193 GRADE B7	ASTM A193 GRADE B7	ASTM A193 GRADE B7	ASTM A193 GRADE B8M
NUTS	ASTM A194 GRADE 2H	ASTM A194 GRADE 2H	ASTM A194 GRADE 2H	ASTM A194 GRADE 2H	ASTM A194 GRADE 8M

304.1.2 Pump Units

All pump units shall have means of isolation from their associated pipework system.

In dry well installations, the suction valve will normally be left open, unless used for isolation when the pump is out of service.

The delivery side of the pump set shall include a non-return device to prevent back circulation when the set is not running. This shall be a fail-safe device such that in the event of pump failure or loss of external services, the device shall independently close eg. ball valves, check valves or gate valves closed by gravity or stored energy systems in exceptional circumstances. A gate valve will normally also be installed on the pump delivery side, downstream of the non return device, for pump isolation.

304.1.3 Pump Unit Control

The pump unit control panel shall include all control and indication elements for the pump motor, together with any associated valve actuators, lubricating systems and valves, cooling fans, flushing pumps and other ancillary control equipment required by a pump drive, all arranged to operate in a safe and proper sequence.

Where external services are required to open the delivery valve, the control system shall initiate the valve opening procedure as soon as the pump is up to a speed sufficient to overcome any existing delivery pressure.

Normal starting sequence will therefore cause the pump to run-up to operating speed then initiate opening of the delivery valve. Normal stopping sequence will first initiate delivery valve closure, after valve has closed then pump motor will be de-energised.

Failure of the valve to open within the time allowed, or closure occurring whilst running, shall initiate an alarm and shut down the pump set. The maximum running time with the delivery valve closed shall be 3 minutes unless otherwise specified.

304.1.4 Pump Duty

Pumps shall be of the type specified in the PS. They shall be designed to give specified output against all losses including those relating to the pump.

The Contractor shall match his pump characteristics to the pipe system network to achieve high pump efficiency and reliability.

Each set must be capable of running satisfactorily in parallel with other sets in the system without throttling and by itself, without cavitation or overload under all operating conditions within the system characteristics given.

The pump section and arrangement shall be such as to ensure that the head available exceeds the N.P.S.H. requirements of the pump under all operational conditions.

Where the system and pump characteristics are such as to give rise to the possibility of surge in the pipeline with consequential damage, a surge investigation shall be undertaken; if the results of the investigation show that there is a problem, measures shall be proposed by the contractor to alleviate the problem. These measures shall be agreed with the Engineer.

Centrifugal pumps shall have a non-overloading characteristic over the complete range of head and quantity delivered and the drive shall be capable of starting the pumps against a closed valve, ie. maximum pump head conditions.

The whole pumping unit shall be capable of withstanding without detriment, reverse rotation to a speed that would occur if the pump were to stop when the differential head was at a maximum and the delivery and/or non-return valve failed to close.

The design of the pumps shall be such that there will be no tendency to unlock any part due to possible reversal of rotation and shall not pass through or approach a critical speed.

The pumps shall be capable of working for long periods without cleaning or attention.

For sewage pumps the ability to operate with the maximum reliability is of prime importance, with efficiency being a secondary consideration. The pump shall operate without clogging, being designed to pass a sphere as specified in Particular Specification (PS) where the size of the delivery mains permits. Whilst the pumps shall be designed to meet a specific duty they shall also be capable of operating over the duty range specified for prolonged periods and for standing idle for long periods without attention as in the case of storm pumping.

304.1.5 Pump Duty Control

Each of the pump units shall be capable of operating in any combination of duty sequence.

Any starting sequence, including those following restoration after a supply failure shall be time sequenced to prevent excessive load on the supply system. Each duty circuit shall include its own timer, arranged to be initiated in the selected duty sequence by the preceding duty, the delay periods between each re-start being adjustable up to 20 secs.

Pumping sets shall be automatically operated according to water levels in the discharge and suction side reservoirs unless otherwise specified.

Successive levels shall be carefully chosen in order to ensure a smooth and safe operation of the pumping system, taking into consideration the characteristics of the pumps, networks, hydraulic inertia of the installation, as well as the sensitivity of the instrumentation.

Two sets of level measuring devices operating in redundancy shall be installed in each reservoir unless otherwise specified.

Where valves with motorised actuator are installed on pump outlet pipe section, the pump shall be started with a closed valve: each pump shall start when the valve is still closed. The valve begins to open at the starting command of the pump and shall be controlled by the discharge pressure. The time of the total opening of the valve shall be chosen according to the pump manufacturer recommendation. At the pump stop command, the corresponding valve shall receive a closing signal and shall close fully prior tot he shutdown of the pump.

Where more than one pumpset is installed for a water network and unless otherwise specified, pumps shall be operated with a cyclic duty program automatically executed by the supervisor system. However, a selection of pump duty order by the operator shall be possible.

304.1.6 Pumps Casings

Pump casings shall be capable of withstanding all pressures which may be produced due to operating pressure surges.

Particular attention shall be paid to the wear characteristics of the pumps. In the case of sewage pumps, due to the presence of grit in the sewage wear, could be appreciable.

The pump design shall ensure that alignment is maintained between the various assemblies by recesses, spigots and dowels and shall be such that all components liable to wear can be replaced.

Components shall be permanently marked with the manufacturer's number and where dowels are not used, permanently marked for correct assembly. The pump casing shall have detachable wear rings.

The casings of the pumps shall have flanges to match the specified pipework.

The waterways through the pumps shall be smooth in finish and free from recesses and obstructions.

Sewage pump casings shall be of substantial construction to give long life under abrasive conditions and suitably stiffened to withstand shock due to solids in suspension. Inspection holes shall be provided in any section bend and in the pump casing above the impeller for access to facilitate the clearance of obstructions. The inspection hole covers shall be shaped to conform to the interior profile of the waterway when in place and shall be fitted with starting screws where necessary.

304.1.7 Impellers

Impellers shall be securely fitted to pump shafts in such a manner to prevent them becoming loose or detached when the pump is in operation, or when rotating in the reverse direction, either by liquid flow or motor rotation.

The impellers and guide vanes (if any) shall be accurately machined and smoothly finished to minimise hydraulic losses.

The rotating elements type shall be specified in the PS and shall be statically and dynamically balanced before final assembly.

For sewage pumps the impeller shall be of the open type with the inlet ends of the vanes being of bulbous design and the impeller passages being as large as possible consistent with good performance. The impeller shall be readily withdrawable from the pump casing without the need to disconnect pipework. The inlet ends and surfaces of the vanes shall be dressed to give a smooth finish to prevent fouling by rags and fibrous matter within the pumps.

Impellers for both sewage and storm water pumps shall be of the non-shrouded type, constructed as specified in the PS, and designed to exclude gritty matter from the shaft and gland.

The impellers should have replaceable wear sings. The clearance at the wear rings shall be kept to a minimum, and where it is found necessary to cut back the impeller this is to be done on the vanes only.

304.1.8 Pump Shaft

The pump shaft shall be as specified in the PS adequately sized, with good fatigue, shock load and corrosion resistance. The duty speed range shall be well below the first critical speed of the shaft. Where a change in diameter of the shaft occurs the shoulder shall be radiussed or undercut to the appropriate BS to reduce stress concentration.

The shaft shall be complete with easily renewable protecting sleeves of suitable material (stainless steel) at glands and bearings.

304.1.9 Shaft Seals

Pump shaft sealing type shall be as specified in the PS.

Pump shaft sealing arrangement shall be suitable for the water pressures and shaft speeds involved.

Pumps shall be fitted with packing glands seals or a split type mechanical shaft seal arranged such that replacement of wearing components can be carried out without the need to dismantle the pump.

Special care in the selection of materials shall be taken in order to avoid binding and electrolytic action between the shaft sleeve and the mechanical seal components, particularly where long periods of idleness are inherent in the duty cycle as in the case of standby and storm pumping.

Each mechanical seal shall be equipped with leakage collection facilities and separately piped as specified.

Pump glands shall be of the soft packed type with wearing sleeves and shall be designed for grease lubrication and shall be provided with large size grease lubricators with tell-tales. Glands and lantern rings shall be of the split type to facilitate easy packing.

Pumps fitted with soft re-packable or packed gland type seals, shall have stuffing boxes designed to facilitate adjustment or replacement of the packing materials.

304.1.10 Bearings

All pumps shall incorporate bearing arrangements which prevent the escape of lubricant into the liquid being pumped. The bearings shall be located in dust/moisture-proof housings.

All bearings shall be liberally rated to ensure cool running and meet the load factors specified.

For vertically mounted pumps, the top bearing shall be a combined thrust and journal type, designed to prevent any thrust loads being transmitted to the drive motor. The pump bottom bearing shall be lubricated by an enclosed water lubricated sleeve bearing for potable water applications but by grease or other approved means for sewage use. Storm pump bearings shall also be suitable for standing idle for periods up to 2 months without attention or movement.

Where grease points are necessary they shall be fitted with removable screwed plugs which shall be accessible without removing guards. All bearings having automatic lubrication shall also have provision for hand lubrication.

304.1.11 Baseplates and Stools

For vertical pump units, heavy cast iron or fabricated steel floor plates and motor stools shall be provided for direct mounting on concrete floors or supporting steelwork. Suitable journal and thrust bearings shall be provided in the baseplates to carry the vertical drive shaft.

Where necessary the motor stools shall be designed to accommodate flywheels and bearing housings.

Floor plates shall be recessed and so arranged that the tops and fixing bolts are level with the finished floor.

The pump units shall be accurately aligned and located on the baseplate by set screws and parallel dowels or machined spigots. Approved means of dowel withdrawal shall be provided.

304.1.12 Lubrication/Cooling Monitoring

A lubrication system shall be arranged for the lubrication of all grease points on the pumps and shafting from motor room level. Individual bearings within the support tunnel tubes and on the pump sets themselves shall receive separate supplies of grease fed by pressure tubes laid from each bearing to battery plates readily accessible from motor floor level for grease gun operation.

Pressure tubes shall be grouped together where possible and securely attached by brackets, straps etc. to tunnel tubes, with connectors located near to the motor support plate for easy removal of shafting in the event of maintenance work. In exposed positions pressure tubes are protected from damage. Motor grease points will not be included in this lubrication system but shall receive individual attention.

The battery plates shall have sufficient greasing points for all bearings and be located on or adjacent to each pump motor stool.

A notice is to be supplied and fixed on the wall in a prominent position detailing the manufacturer's recommended greasing schedule. The notice shall include a warning of the dangers to bearings from `over greasing'.

A grease gun shall be supplied for all greasing purposes.

Bearings which require a continuous supply of lubricant shall incorporate a means of monitoring such a supply, either by flow or temperature rise as appropriate for the type of bearing employed; separate monitors being fitted for each bearing feed or housing.

Such monitors shall include all necessary ancillary power or pulse counting devices to enable the operation of any monitor to initiate a volt free contact rated at 240V 0.5A AC.

304.1.13 Pump Tundish

Where specified, each pump shall be equipped with a cast aluminium or fabricated steel tundish to accommodate the drain lines from mechanical seals, casing vent and other minor drainage points on the pump. A single drain pipe shall be run from the tundish to the house drainage system.

304.1.14 Air Release Cock

The highest point on the pump casing shall be fitted with a manual air release cock having a removable handle or an automatic air release valve with a lockable isolation valve as specified. Air release pipework on sewage pumps shall be not less than 30mm bore and shall discharge back into the wet well at high level and have facilities for rodding. The drain from each air release cock shall discharge via pipework as specified.

304.1.15 Couplings

Coupling materials shall be chromium stainless steel.

All couplings shall be of an approved type and the Contractor shall arrange for the provision and fitting of both coupling halves to each respective shaft and shall include for all necessary modifications to any existing shafts to be coupled.

Where specified, the Contractor shall include any equipment required to prevent damage to any part of the drive in the event of reverse rotation of the pumps.

304.1.16 Intermediate Shafts

Intermediate shafts between the pump and drive shall include universal couplings at each end allowing free axial movement to avoid end thrust being transmitted. The shaft and coupling shall be fitted with a full length guard manufactured from mild steel mesh on a mild steel framework, easily removable for maintenance purposes.

The frame and mesh shall be hot dip galvanised.

304.1.17 Gear Unit

Each unit shall be continuously rated to transmit the full power of the drive either directly in line or through a right angled, helical gear system, having an input/output speed ratio to suit the duty.
The gear case shall be made of substantially ribbed cast iron with machined mounting feet and shall form a totally enclosed, oil tight casing.

The gear unit case and bearings shall be designed to accommodate the total weight of any suspended drive shafting and couplings in addition to any dynamic load imparted during service, and run for a minimum of 10,000 hours before a major overhaul is required.
Where specified, an electric tachometer shall be fitted to indicate the output shaft speed.

(i) Lubrication

The gear unit shall be grease or oil lubricated, arranged to provide an adequate supply of lubricant for the duty.

Where oil lubrication is employed, the casing shall include an oil breather, level indicator and drain plug.

Units having a rated output greater than 500kW shall have inspection covers and include a forced lubrication system comprising an oil circulating pump, reservoir tank and full flow `Duplex' type oil filters having re-usable elements together with associated pipework; the oil being circulated by either (a) an internal mechanically driven gear pump and an external electrically driven pump arranged to prime the gears as pre-set timings as recommended by the unit manufacturer, or (b) duplicate external electrically driven pumps, each of which may be selected to prime at pre-set intervals and run when the gear unit runs.

Such a lubrication system shall include dial gauges and alarm switches to monitor high oil temperature and low oil pressure.

(ii) Reverse rotation

Where specified, the gear unit shall be capable of withstanding reverse rotation for a limited period with no detriment to the unit. Where a forced lubrication system is used, this shall continue to operate satisfactorily under such conditions.

304.2 SUBMERSIBLE PUMPS FOR SEWAGE & RIVER WATER APPLICATION

The pumps shall be fully submersible and of the unchokeable type, capable of passing raw unscreened sewage. They shall have non-overloading characteristics and incorporate bearings sealed for life.

The sealing arrangements between pump and motor shall be by means of mechanical seals running in an oil bath which serves to lubricate and cool the interfaces of the seals.

The pump shall include renewable and easily replaceable wear rings.

Robustness of construction and the ability to operate automatically with a minimum of attention for long periods is essential.

The pumps shall be supplied with guide rails unless otherwise stated, and particular attention shall be given to the free passage of the pumps up and down the rails without jamming. The pump outlet flange, unless otherwise stated, shall have a boltless coupling on to the flange of the fixed delivery pipework and shall have positive location so as to provide an automatic coupling with a good seal when the pump is lowered into position.

The pump casing shall incorporate a lifting eye of not less than 80mm internal diameter suitable for the attachment of heavily galvanized lifting chains which shall be brought out of the wet well to a conveniently sited fastening. For electrical details, see Volume 3, Part 4 - Electrical Works.

Unless otherwise specified, sewage pumps shall be equipped with a flushing system that shall stirr the water in the sump prior to the start of the pumping cycle. The stirring shall be effective by putting sludge and solid particles into suspension and shall prevent the build up of sludge banks and debris on the sump floor.

304.3 PROGRESSIVE CAVITY PUMPS

The pump casing shall be manufactured in a close-grained cast iron in accordance with BS 1452, or in grades of stainless steel to suit the nature of the pumped liquid. The pump casing shall be pressure tested in accordance with BS 599.

The pumping element shall consist of a single helical rotor revolving within a resilient stator. The stator/rotor shall be designed in accordance with the normal operating conditions, taking into consideration temperature, corrosion, abrasion and reliability under maximum torsional load. The rotor material shall be stainless steel either ceramically coated or chrome plated in accordance with the relevant requirements of BS 970: Part 1.

The rotor's eccentric motion shall be facilitated by either a flexible drive shaft or by fitting a universal joint between the motor and drive unit. This motion shall permit a continuous seal line throughout the pumping element thus giving a constant positive displacement. The flexible or coupling rod drive shall be of a high strength stainless steel with an impermeable thermoplastic or equal coating to provide resistance to abrasion and corrosion.

The pump drive assembly may be directly coupled or arranged for a guarded toothed-belt drive arrangement. The pump speed shall not exceed 500 rpm.

Under no circumstances shall any grade of aluminium be employed in the fabrication of the pump's wetted parts.

All working surfaces shall be accurately machined and provided with deep registers, where necessary, to ensure true accurate alignment. The pump casing shall be capable of being fitted with a replacement rotor and stator components. Tapped bosses shall be provided for drainage purposes and suction and delivery gauge connections.

304.4 SCREW PUMPS

Screw pumping units shall be suitable in all respects for pumping crude sewage and returned activated sludge and for running continuously at all outputs up to the specified maximum. All parts and components shall be fully weather-proof and suitable for use out of doors.

i) Drive Arrangement

Each pump shall be driven by an electric motor, the drive being transmitted from the motor to the screw, either directly through a reduction gearbox or else through a V-belt drive and gearbox.
The gearbox shall have oil bath lubrication and shall be provided with an inspection cover, oil breather and oil level indicator. The gears shall be rated for continuous duty.

Connection between the drive unit and screw shall be by means of a pin-type flexible coupling with rubber bushes, or other approved flexible coupling.

If a V-belt drive is used ready means of belt tension adjustment shall be provided.

Means shall be provided to prevent reversal of rotation on shut down.

ii) Bearings and Lubrication

Each pump shall be complete with top and bottom bearings, driving mechanisms and automatic lubricators, all supplied and installed as a unit by one manufacturer.

The top bearing shall be designed to accommodate the main radial and axial loads which occur on the screw and shall be suitable for high pressure grease lubrication. The bottom bearing shall be of the bronze sleeve type secured in a watertight cast iron housing and designed to accommodate radial forces and end support load. The housing shall be mounted on a fabricated steel pedestal and plate which shall be swivel mounted to allow them to take up correct alignment on installation. The bearing shall be fitted with an external stationary shroud to prevent debris affecting the moving parts.

Lubrication shall be automatic from a grease or oil lubricator, the lubricator pump being driven by an electric motor or from the main drive. A friction drive is not acceptable. A `tell tale' indicator in the case of grease, and flow indicator in the case of oil, shall show that lubricant is passing to the bearing. Oil shall be returned from the bearing to the oil reservoir.

In the case of an electrically driven lubricator the electric drive shall be interlocked with that of the main pump drive so that the screw pump will not run without the lubricator. A warning light shall indicate `lubricating pump failed'. Where other means of driving the lubricator pump are used provision shall be made to stop the screw pump if the lubricator drive fails for any reason.

iii) Installation and Guards

Each screw pump shall be suitable for mounting in a concrete trough and shall be supplied complete with steel side profile member. Each screw shall also be supplied with a steel splash plate to fit round the shaft and seal the hole where the upper end of the screw passes through the wall into the motor room. The screw and its driving mechanism shall be such that they can be safely used to form the final screed of the concrete trough in which the screw rotor runs.

All equipment offered shall be designed to keep maintenance to a minimum, and to provide maximum safety to operatives and maintenance staff. Protective guards shall be fitted over all moving parts to prevent any possible contact.

304.5 DOUBLE DISC PUMPS

The double disc pump shall comprise two reciprocating, mechanically driven, tough resilient discs with a sufficiently large cavity between the discs to produce displacement in a smooth continuous flow.

The pump shall be valveless and glandless and be capable of operating dry indefinitely without pump damage occurring.

The double disc pump shall be available as a static or mobile unit, as specified. It shall be suitable for either electric motor or diesel engine drive, as specified.

The pump body shall be manufactured from cast iron to BS 1452 Grade 220, as a minimum.

The discs shall be manufactured from Nitrile rubber or equivalent.

304.6 DIAPHRAGM PUMPS

The pump shall be of the diaphragm type utilising a bullfrog type valve, suitable for pumping viscous solutions containing solids up to 55mm diameter as specified. It shall be driven by an electric motor through an oil bath reduction gear unit.

The main body of the pump shall be manufactured from LM6 aluminium and all wetted parts shall be supplied in 316 stainless steel.

The diaphragm shall be manufactured from neoprene, nitrile, hyperlon or viton elastomers and shall be reinforced with polyester fabric.

304.7 SUBMERSIBLE BOREHOLE PUMPS

Pumps impellers shall be closed or semi open type.

Pump body shall be treated against corrosion. The bowls shall be joined by flanges or by tie roads.

The shaft main guide bearings located in the suction and delivery end housings of the pump shall utilise a leaded-bronze material, and shall be provided with protection guards to prevent ingress of sand and grit. Pump bowl guide bearings shall utilise either leaded bronze or other approved abrasion resistant material. All pump bearings shall be lubricated by the water to be pumped. The pump delivery end housing shall incorporate a thrust washer of suitable material at the shaft end to absorb upthrusts that occur during pump starting. Unless otherwise specified, the pump shall incorporate a delivery check valve of hydrodynamic shape fitted with a spring to prevent reverse rotation of the shaft from back flow of water through the pump. The pumps shall be provided with a flanged discharge connection suitable for operating against the pump closed valve head or 16 bar whichever is the greater. The shaft coupling connecting the pump and driving motor shall be accurately machined and keyed to ensure precise shaft engagement and alignment. A strainer of suitable corrosion and abrasion resistant material, designed to guard against entry of foreign matter but permitting unrestricted flow of water into the pump, shall be provided on the pump suction housing.

Protection against the effect of sand shall provided by renewable wear rings (made from a hard smooth flexible material such as polymethane) mounted at the seating of the impellers and the passages of the shaft.

The pump shall be designed to pump water having a sand content of up to 40g/m3, unless otherwise specified

A centraliser shall be fitted to every pump to ensure central alignment of the pumpset in the borehole casing.

304.7.1 Borehole Pumps Rising Column

Borehole rising column shall be seamless steel and provided in section lengths not exceeding 3 metres with flanged joints or screwed couplings according to API5L grade B or equivqlent. The rising column shall allow for small deviations in borehole verticality. Cables and and water level dip tubing shall be securely fixed to the rising column by straps or bands at approximately 2 metre intervals.

The rising column shall be sufficient to take the stresses generated by the hanging weight of the pump, motor and rising column, the stresses produced by the water pressure together with any dynamic stresses which may occur under any circumstances including valve closure.
The rising column shall be protected internally and externally in factory against corrosion by a non toxic epoxy resin coating (300 μm minimum thickness) suitable for use with potable water.

304.7.2 Borehole Pumps Headworks

A fabricated steel discharge head piece shall be provided at the top of the borehole to support the complete rising column and electro-submersible pumpset assembly, and shall be complete with lifting eye bolts. The discharge head piece shall comprise a heavy duty sealing plate arranged for bolting to the borehole outer casing flange, and a 90º discharge bend arranged for flanged connection to both rising column and horizontal surface pipework. Lifting eyes shall be provided in the sealing plate. A flange shall be provided and welded by the Contractor to the top of the borehole outer casing. The flange shall be suitably drilled to accommodate the discharge head piece sealing plate bolts. Holes shall be provided in the sealing plate to accommodate an air vent pipe, motor and control cables, water level dip tubing, etc. and shall include adequate sealing arrangements to protect against borehole contamination.

A 25mm diameter screwed removable plug shall be provided over the dip tubing for water level measurement with electrical contact tape. A stainless steel air vent pipe shall be fitted to the discharge head sealing plate, terminating in an insect proof screen and arranged to prevent entry of rain or surface water.

304.8 VERTICAL TURBINE PUMPSETS

The pumps shall be of the vertical line shaft type. The discharge head shall be bolted onto a substantial steel bedplate or frame which shall in turn be bolted to the pump room floor. The discharge head shall have a flanged discharge. Replaceable seal rings shall be fitted on the impeller suction side if required to maintain pump hydraulic efficiency.

The pump shaft shall be of chromium stainless steel (13% chromium) minimum supported by bearings above and below each stage. Protection shall be given against the effects of entrained solids in the water being pumped intermediate bearings shall be lubricated by the liquid being pumped.

The line shaft shall be of the same material as the pump shaft, supplied in lengths not exceeding 3.0m, with screwed couplings. The line shaft bearings shall be spider type to locate the shaft in the tube and may also double up as line shaft tube couplers. Lubrication shall be provided to the bearings.

The pump suction shall be of at least equal diameter to the pump and shall be fitted with a suction strainer.

Means shall be provided of adjusting the pump shaft tension and position.

304.9 CHEMICAL METERING AND DOSING PUMPS

Chemical dosing shall be by means of electrically driven metering pumps unless otherwise particularly specified.

Metering pumps shall be of the plunger or progressive cavity type.

The effective range of the metering pumps shall be between zero and maximum with an overall repeatable accuracy within ±3%. Output shall be adjustable through a stepless variable stroke mechanism in the case of plunger pumps and variable speed motor or gearbox in the case of progressive cavity pumps.

The metering pumps shall be manually adjusted, and shall be calibrated to allow setting at the required dosage. Dose adjustment shall be possible whilst the units are in operation. Accurate dosing shall be maintained down to 10% of the maximum dosing rate.

The Contractor shall consider the liquid to be pumped and select the materials of construction so as to avoid corrosion. Mechanical glands are generally undesirable but where unavoidable, shall be to the approval of the Engineer.

For metering pumps of the plunger type the materials in contact with the liquid shall be polypropylene, stainless steel grade 316, UPVC or PTFE. Plungers shall be a high-alumina ceramic or stainless steel, grade 316.

Metering pumps shall be mounted on bed plates which shall be protected from gland drip. The pumps shall be driven by close coupled motors with reduction gears and have mechanisms housed in a totally enclosed oil bath.

At least one standby pump, fully connected into the chemical dosing system, shall be provided for each chemical, with local manual selection of duty and standby units. When pump duty change-over is effected the appropriate suction and delivery isolating valves shall be manually operated.

Stators and rotors for progressive cavity pumps shall be of materials selected having regard to the liquids being pumped.

The design and location of the metering pumps shall be such as to facilitate easy dismantling for the removal of any foreign matter.

Flushing facilities shall be provided for all chemical pipework at the inlet and outlet of each metering pump, together with drip trays to contain any spillage or leakage and piped to the nearest drain point. Provision shall be made for priming the systems to eliminate any air.

Each chemical dosing pump shall be provided with suitable isolating valves, an inter-connecting manifold system and, where necessary, loading valves. A calibrated glass container shall be provided connected into the suction manifold of each chemical pump so that its output can be checked.

Calibration curves shall be provided by the Contractor for all chemical dosing pumps.

304.10 PACKAGED BOOSTER SETS FOR COLD WATER SUPPLY

General

The set shall be a self-contained, fully automatic packaged unit which requires the minimum of maintenance to give maximum trouble-free operation. The systems consist of either 2, 3 or more individual pump and motor units which operate independently of one another and react immediately to fulfill system demand.

Each set incorporates diaphragm pressure vessels ready with a supply of water when demand arises. When draw-off exceeds the vessel’s storage capacity, the lead pump is automatically started by a pressure switch to cope with the demand. In the event of unusually high demand, or failure of the lead pump, the support pump (or pumps) will immediately start.

Pumps

Vertical multistage or horizontal end-suction centrifugal pumps.

Control panel

Sheet steel enclosure incorporating all electrical components necessary for an automatic operation of the pumpset. Interwired with motors and pressure switches, requiring only connections to main supply on site. In the event of malfunction of any pump a stand-by pump will start automatically and panel will visually identify the faulty unit. The control panel in corporates a manual selector switch to allocate the role of lead pump in turns, to ensure an even distribution of work load.

Motors

Totally enclosed fan cooled (TEFC) direct-coupled motors, for 50 Hz supply, 380 voltages class F insulation.

Pressure vessel

Mild steel construction incorporating replaceable non-toxic butyl rubber diaphragm. Factory pre-charged to required pressure, eliminating the need for a compressor on site.

Valves

Each individual pump has an inlet and outlet isolating valve and a non-return valve on the discharge of each pump. This allows any pump to be removed from the set without the necessity to shutdown the system. An isolating valve is fitted on the pressure vessel line.

Pressure manifold

Each pump is controlled by its own individual pressure switch, factory set for system requirements and mounted with a common discharge pressure gauge on an aluminium manifold block. Receiving their signal through a high pressure PVC pipe which is connected to the discharge pipework.

Pipework

Pipework supplied in copper.

Baseframe

To be fabricated from 6 mm, flat mild steel plate, complete with panel support and holding-down lugs drilled and tapped to secure all pumpset components.

305. VALVES & PENSTOCKS

305.1 GENERAL REQUIREMENTS FOR VALVES

305.1.1 General

Small valves of ND less than or equal to 40 mm shall be provided with self locking handles or handwheels to prevent accidental operation.

Emergency isolation valves shall be gate, ball or plug valves.

Drain and vent valves shall be provided with a plug or blind on the discharge side.

Flangeless valves shall not be used as the first block valves against storage tank.

Unless otherwise specified, valves shall be epoxy coated internally and externally. The coating shall have a minimum thickness of 150 µm.

Threaded ends shall not be used for valve sizes larger than 50 mm ND.

All handwheels, headstock, foot brackets, guide bracket and thrust tubes shall be of cast iron.

Fixing nuts and bolts supplied by the manufacturer shall be as specified in the general requirements for fastners.

Valves shall be sized such that the velocity through the valve when fully open does not exceed 2.50 metres per second at the rated throughput. They shall have flanges to not less than BS.4504 NP.16 and shall be capable of withstanding the same test pressures as the pipeline on which they operate. All nuts and studs subject to vibration shall be fitted with spring washer or locking tabs.

305.1.2 Types and Operating Conditions

Valves shall be designed to meet the operational and environmental conditions specified for the types indicated in the specific valve schedule.

The closure rates of all valves shall be designed to prevent the effects of surge. Where necessary, valves with a varying closure rate shall be used.

Valve flanges or couplings shall be as specified in the valve schedule and match those specified for the pipework installation.

305.1.3 Identification

Each valve shall be identified by a unique reference as approved which shall identify the medium/plant controlled and be numbered in a logical sequence.

The reference shall be either engraved on a 3mm thick laminated white/black/white traffolyte disc or stamped on a 1.0mm (19g) thick brass disc. The discs shall be at least 35mm dia. with reference letters and numerals not less than 4mm and 8mm high respectively.

The discs shall be mounted on the hub of the handwheel or where this is impractical, they shall be attached to the valve stem by means of suitable brass 'S' hooks and/or jack chain through a hole at the top of the disc.

305.1.4 Access

All valves, spindles and handwheels shall be positioned to give good access for operational personnel. It shall be possible either to remove and replace or to recondition seats, gates or gland packings which shall be accessible without removal of the valve from the pipework or, in the case of power operated valves, without removal of the actuator from the valve.

Extension spindles shall be supplied wherever necessary to achieve the specified operating requirements.

305.1.5 Hand Operation

All handwheels shall be arranged to turn in a clockwise direction to close the valve or penstock, the direction of rotation for opening and closing being indicated on the handwheels.

The handwheels shall be coated with black plastic and incorporate facilities for padlocking in either the open or closed position.

Bituminous paints shall not be applied to any valve handwheel.

The operating gear of all valves and penstocks shall be such that they can be opened and closed by one man against an unbalanced head 15% in excess of the maximum specified service value and any gearing shall be such as to permit manual operation in a reasonable time and not exceed a required rim pull of 55kgf.

Power operated valves shall include equipment for manual operation by means of a handwheel or other suitable device which shall be interlocked with, and fixed to, the power unit.

Headstocks and valves of 125mm nominal bore and above shall be fitted with mechanical position indicators to show the amount which the valve is open or closed in relation to its full travel, i.e. 0.25, 0.50, 0.75, 1 etc.

305.2 VALVE MATERIALS

Valve bodies and other components shall be of corrosion resistant materials, compatible with the medium and of robust industrial design.

For water applications and where specified, valve bodies, discs and wedges shall be of cast iron, with facing rings, seating rings, wedge nut and other trim of corrosion resistant bronze or gun metal.

The valve stem, thrust washers, screws, nuts and other components exposed to the water shall be of a corrosion resistant grade of bronze or stainless steel.

For water works applications, wedge gate, metal seated valve materials shall be in accordance with BS 5163 Table 6A, fitted with a stuffing box and gland seal on the stem. Oil or grease shall not be used on any bearing or seal that may be in contact with the water being controlled.

The type and size of valve to be used to any particular location shall be as indicated on the contract drawings. Valve materials shall comply with the following minimum requirements.

ENVIRONMENT	BODY	TRIM**	REMARKS
Air	Carbon Steel or Bronze	410 SS Bronze	Blower discharge valves can be supplied to blower manufacturer standard.
Cl_2 Gas	Carbon Steel	410 SS	
Cl_2 Water	PVC	PVC	
Diesel Oil	Carbon Steel	410 SS	
Sewage	Ductile Iron Cast Iron PVC	Bronze* Bronze* PVC	Zinc free.
Potable Water	Bronze PVC Ductile Iron Cast Iron	Bronze* PVC Bronze* Bronze*	Less than 1000 mg/l total dissolved solids. Zinc free.

* Alternate acceptable materials for stem is aluminum bronze, or nickel aluminum bronze

** Trim material includes stem, body and closure seating surface, seat rings, bushings, springs, or any small parts in contact with service fluid.

305.3 SLUICE VALVES

All sluice valves, unless otherwise specified shall be of the rising spindle type, have wedge gates and be in accordance with the relevant clauses of BS 5150 and BS 5163.

Valves up to and including 300 mm ND shall be of the resilient seal or metal seal type. Valves larger than 300 mm ND shall have metal seals.

The valves shall be suitable for unbalanced head. A by-pass with gate valve forming an integral part of the valve shall be provided where recommended by the manufacturer for the pressures specified.

Where specified, sluice valves shall be fitted with easing screws and a clean-out box in the base.

Unless otherwise specified, each valve shall be provided with a suitable handwheel of adequate diameter for the duty required. Gearing shall be supplied where necessary, to ensure that the required operating force applied by hand to the rim of the wheel does not exceed 55 kgf.

Stem seals shall be of the stuffing box and gland type, arranged for easy replacement of packing and shall be accessible for maintenance without removal of the valve from service.

Extension spindles, headstocks and foot brackets shall be provided where required.

Where valves are required to be operated by tee keys spindle caps shall be fitted. The caps shall be drilled and each provided with nut and bolt for securing to the spindle, which shall likewise be drilled to accept the bolt. Each cap where fitted shall be supplied complete with operating tee key.

305.4 TELESCOPIC VALVES

All bellmouth telescopic valves shall have cast iron outer sleeves and bellmouths. The outer sleeves shall have machined labyrinth seals and the sliding tubes shall be manufactured from zinc free bronze.

A cast iron stirrup shall be affixed over the top of each bellmouth and these shall be connected to the rising screw thread by means of a stainless steel 'Rose' type coupling. To minimise fouling by rags etc. the valves shall not be fitted with outer guide rods.

305.5 NON-RETURN VALVES

Check valves shall comply with BS 5153.

All non-return valves shall be of a type that will operate without shock.

Valve bodies shall be of cast iron unless otherwise specified and shall be fitted with renewable type seatings.

Covers shall be provided to allow ample access for cleaning and service and shall be supplied complete with tapped bosses.

In the case of swing gate type valves the hinge pin shall be of stainless steel, mounted in zinc free bronze bushes and extended and fitted with external levers and counter balance weights, all protected by a screen guard.

Other types of valves will be considered. In every case the non return valve shall be selected with full consideration of the system characteristics, and shall avoid valve slam, and have low maintenance requirements.

Where specified, limit switches shall be provided to operate from the external lever. The screen guard being slotted to allow the guard to be removed without disturbing the switch cabling.

305.6 BUTTERFLY VALVES

Butterfly valves shall have a resilient disc seating and be designed for a positive leak-proof shut off at a minimum pressure of 16 bar. Non-wafer types are preferred.

Butterfly valves shall conform to BS 5155

The disc shall be in grey or ductile cast iron unless otherwise specified with a resilient seating ring in moulded rubber, or other material to the approval of the Engineer.

For valves of 350 mm ND and above, a suitably lubricated axial thrust bearing shall be fitted.

A stuffing box and gland shall be fitted on the operation shalft extension to seal the pressure side of the valve. The design shall be such as to facilitate packing replacement without removal of the valve from the pipeline.

A valve position indicator, to show the position of the disc, shall be provided on the valve operating gear.

Suitable stops shall be incorporated to prevent movement beyond the disc "fully open" and "fully closed" positions.

Valves for flow regulation shall be of all metal construction.

305.7 PLUG VALVES

Plug valves shall be of the wedge gate type, with cast bodies. The plug surface shall be coated or lubricated to ensure low torque operation with bubble tight shut-off and 'non-sticking' materials.

305.8 SLIDE VALVES

Unless otherwise specified, slide valves shall be of the lightweight pattern type with cast or ductile iron body, stainless steel slide and chromium steel outside rising screw spindle.

The valve body shall incorporate a transverse slide seal so arranged for easy replacement of the packing, which shall be accessible without removal of the valve from the pipeline.

Handwheels shall have smooth rims and of such diameter to enable one man to operate the valve. The direction of opening and closing shall be cast on the handwheel. The direction of closing shall be clockwise.

Valves of 125 mm, nominal bore and over shall be fitted with position indicators showing the amount which the valve is open or closed in relation to its full travel.

305.9 ISOLATING COCKS

For isolation of small bore pipework tappings for instrumentation equipment etc. and for individual component isolation, the cocks shall be stainless steel, quarter-turn, ball or plug valves with the operating handle arranged to indicate the open and closed positions. Where specified, means shall be provided for securing the valve body to a front panel or rear surface.

Where corporation cocks are specified, these shall be similar to the above isolating cocks but shall have a detachable key handle for fitting onto a squared operating shaft, the shaft end being marked to indicate the open and closed valve positions.

305.10 PENSTOCKS

305.10.1 General

All penstocks shall be designed and installed so that the maximum working pressure acts in a seating direction on the gate.
Both gate and frames shall be sufficiently rigid to withstand twice the maximum working pressure and any eccentric pressures created by the tightening of the anchor bolts during installation. All penstock frames shall have a spigot back.

The frame shall be designed to ensure that the gate is supported over not less than two thirds of its depth when the gate is fully raised.

Penstocks shall be of the rising spindle type unless otherwise specified, and the spindles shall be of adequate size to avoid buckling under load.

All spindle nuts shall be self aligning and their length shall be not less than twice the spindle diameter.

The top part of the penstock frames shall be sufficiently robust and substantial to prevent the frames bowing and if necessary, additional holding down bolts shall be fitted. The penstocks shall be fitted with matching wedges on doors and guides, the wedges shall be fitted with renewable seatings of zinc free bronze. Under no circumstances shall wedges be fitted to the bottom or lower sections of the penstock doors. The wedges shall be adjustable with stainless steel adjusting screws and shall be readily removable.

On rectangular penstocks the inverts shall be flush with renewable synthetic rubber seals on the bottom of the doors. The rubber shall be suitable for the application and of an approved type.

The doors shall have lifting eyes cast in, or eye bolts of sufficient size to permit the lifting of the door against seating pressure.

Where extended spindles installations require to be operated at elevated floor level, spindle guides or guide brackets shall be provided close to the floor level.

Where penstocks are required to be operated by the tee keys, spindles caps shall be fitted. The caps shall be drilled and each provided with nut and bolt for securing to the spindle which shall also be drilled. Where caps are fitted they shall each be supplied complete with operating tee key.

All penstock shall be provided with headstocks (except where the Handwheels can be mounted on the penstock frames). For penstocks of 300 mm ND. (square or circular) and above and for all motorized and actuator operated penstocks, unless otherwise stated, thrust tubes shall be provided between the penstocks frame and the headstock, in order to absorb the operating thrust in both directions. Thrust tubes shall incorporate all necessary fixing brackets and spindle quid plates.

Headstocks and foot brackets shall be provided for non-rising spindle penstocks where the latter are specifically called for. Guide brackets shall be provided where necessary. Non-rising spindles shall be fitted with thrust collars and arranged so as to transmit the thrust arising from operation of the penstock directly to the Penstocks frame. Where headstocks are required on non-rings spindles installations they shall incorporate a penstock position indicator.

Penstock shall be water-tight under the conditions of head and direction of flow as stated in the appropriate clause or schedule of the specifications and/or the contract drawings.

Penstock shall be water-tight under the conditions of head and direction of flow as stated in the appropriate clause or schedule of the specification and/or the contract drawings.

All bolt holes shall be drilled and spot faced.

Simple templates shall be supplied as soon as possible after approval of drawings to enable the Civil contractor to position the holes for holding down bolts for all penstocks over 1.0 m square.

305.10.2 Penstock Materials

Penstock doors, wedge support beams, frames, guides, frame extensions, headstocks and bridge pieces shall be cast iron, of minimum grade 220 to BS 1452. Doors and frames shall be fitted with renewable seatings of zinc free bronze.

Spindles shall be manufactured from stainless steel 431S29 (EN 57) or similar approved material.

305.10.3 Extension Spindles

Extension spindles shall be adequately sized to prevent buckling and shall be attached to the valve/penstock stem by a suitable adaptor incorporating two muff couplings, scarf lap jointed and pinned with at least two coupling joints included. Universal joints and waterproof sleeves shall be provided where specified. Extension spindles shall be manufactured from 080M40 (EN 8) steel.

Intermediate bearing support or guide brackets of cast iron, with slotted holes for site adjustment, shall be fitted to long shafts where necessary. Bearings shall be of PTFE or similar approved type.

305.10.4 Pedestals and Spindle Covers

Penstock and valve pedestals shall be of cast iron or heavy duty, welded, mild steel construction with a substantial base and fixing provision. The base and top of the pedestals shall be machined normal to the axis of the drive shaft.

Where necessary, support guide bushes shall be fitted as the base of the pedestal.

The pedestal height shall be such that the handwheel is approximately 1 metre above the operator's floor level.

Clear polycarbonate covers of an approved type shall be provided for all rising spindles to totally enclose them when in the fully raised position.

Each tube shall be clearly and permanently engraved to indicate the position of the penstock.

305.11 AIR VALVES

Air valves shall be of two types:

a) Single (small) orifice valves (SOV), for the discharge of air during the normal operation of the pipeline.
b) Double orifice valves (DOV), consisting of a large orifice and a small orifice. These shall permit the bulk discharge of air from the main during filling and air inflow when emptying in addition to the discharge of small quantities of air during normal operating conditions.

Air valves shall be supplied with an independent isolating butterfly valve (DOV) or cook (SOV) which permits the complete removal of the air valve from the main, without affecting the flow of water in the main.

The sizing of the air valve and isolating assembly shall be such that the pressure drop at design flow capacity does not exceed 0.5 bar.

Each air valve assembly shall be suitable for connection to a flange on the pipeline.

At the connection between the air valve and its isolating valve a BSP tapping shall be made suitable for fitting of a pressure gauge. All tappings shall be sealed by a brass plug and copper compression ring gasket.

Air valves shall operate automatically and be constructed so that the operating mechanism will not jam in either the open or closed positions.

305.12 HANDSTOPS (FOR SEWAGE ONLY)

Handstops shall have cast iron frames with galvanised mild steel doors.

Handstops shall be semi-circular or rectangular pattern according to the application or as specified.

Handstops shall be suitable for channel or wall mounting according to the installation requirements.

Handstops doors shall be provided with hand-slots to facilitate operation and a peg and chain shall be provided to hold the door in the open position. Pegs and chains shall be of stainless steel.

On deep channels or where specified, handstop doors shall be provided with lifting handles. Lifting handles shall be of identical material to the doors and guide/retaining brackets shall be provided.

All materials used in the manufacture of handstops shall conform with the requirements for Penstocks specified herein.

305.13 FLAP VALVES

Flap valves shall be of the following categories :

i) General purpose (excluding category (ii) applications).

ii) Seawater and other aggressive applications.

Flap valves shall be normally closed, by weight of the door only, and shall open under minimum flow conditions. They shall be capable of withstanding 1.5 times the specified maximum seating head.

Flap valves on tidal installations shall be capable of withstanding a minimum static head of 6 metres and a minimum surge head of 10 metres.`

Where flap valves are required for flange mounting, they shall be supplied with rubber gasket and the full number of holes to BS.4504 NP 16.

Fixing nuts and bolts shall be as specified in the fastners general requirements with the exception of seawater and other aggressive locations in which case they shall be of stainless steel only.

All flap valves shall be operated and painted in accordance with metal painting and protection requirements.

General purpose flap valves shall be of the double hung type and all valves of 600 mm opening and above shall be of the double door type.

All doors shall be provided with lifting rings and those of 600 mm opening and above shall be fitted with galvanised lifting chains.

305.14 PRESSURE RELIEF VALVES

Pressure relief valves shall protect pipes from accidental overpressure and surge.

It shall consist either of a low inertia valve guided by a flexible diaphragm ensuring a rapid response, and easily adjusted on site, or of a spring operating under compression, a fixed tapered discharge nozzle and a flat-disc mobile shutter.

These valves shall only open under a determined pressure slightly higher (almost 5%) than the maximum pressure for normal working conditions.

The body, sleeve, and gland shall be cast iron. The spring shall be stainless steel.

They shall be wafer type and occupy minimal space.

305.15 PRESSURE / FLOW CONTROL VALVES (REDUCING/REGULATING)

Control valves shall function efficiently of line pressure or flow without human intervention. They shall be hydraulically or electrically operated depending on the availability of a power source. The basic valve shall be heavy duty globe type to BS 5152 & 5160. It shall have no packing glands or stuffing boxes and shall be maintained with ease without removal from the pipeline.

The valve shall be coated internally and externally with epoxy 150 µm minimum thickness. The material of the valve and its elements shall be selected to suit the fluid in the line and the environmental factors such as abrasion, corrosion, pressure and temperature.

306. FASTENERS

306.1 GENRERAL REQUIREMENTS

All fastenings and accessories in contact with the process water shall be of stainless steel, cadmium plated mild steel or other corrosion resistant material subject to the approval of the Engineer. All bolts, nuts, screws, washers and other fixings for anchoring the plant to walls, floors, ceilings, etc. shall be of corrosion resistant material or shall have a protective surface treatment to the approval of the Engineer.

All bolts in inaccessible positions shall be secured by either self locking nuts, spring washers and nuts, or castle nuts with split pins. Fasteners associated with items requiring removal during routine maintenance shall be of stainless steel. All other items shall be sheradised or hot dip galvanised in matched condition.

306.2 BOLTS & NUTS

All bolts, nuts, studs and studbolts, including those required for installation at terminal points to existing equipment, shall be provided by the Contractor and shall have metric threads to BS 3643.

After tightening, the minimum engagement of the thread shall equal the thickness of the nut. The projection of the thread beyond the outer face of the nut shall not exceed one quarter of the outside diameter of the thread. In no circumstances shall galvanised or coated bolts be shortened by cutting.

Washers 3 mm thick shall be provided under all nuts and bolt heads.

All bolts, nuts, washers and anchor plates, except high tensile, for all ferrous parts shall be steel galvanised to BS.729 or sheradised to BS.4921 Class 1, primed and painted after assembly and tightening.

All bolts, studs, nuts, washers and anchor plates, for fastening aluminium alloy components shall be of stainless steel grade 316S16 to BS.970 and shall remain unpainted. PTFE washers shall be fitted beneath stainless steel washers for both bolthead and nut.

All bolts, nuts, studs and washers used in the construction of submersible pumps shall be stainless steel grade 316S16 to BS.970.

306.3 HOLDING-DOWN & ANCHORS BOLTS & NUTS

All holding-down and anchor bolts, nuts, washers and anchor plates for use externally or in internal areas which are subject to contact with sewage or effluent or in "wet" areas but above the top water level shall be of high tensile stainless steel grade 316S16 to BS.970.

All holding-down and anchor bolts, nuts, washers and anchor plates for use internally in areas not subject to contact with sewage or effluent shall be steel galvanised to **BS.729** or sheradised to **BS.4921** class 1 and all exposed surfaces shall be painted after assembly and tightening.

All holding-down or foundation bolts shall be supplied and shall be complete with hexagon nuts and washers. Bolts of steel round bar formed into a loop at one end are not acceptable.

306.4 RIVETS

Rivets are to conform to the appropriate British Standard and for general use pan heads are preferred. Rivets on bearing surfaces are to be flat countersunk, driven flush. Whenever practicable, riveting is to be done by hydraulic tools and the rivets must completely fill the holes when closed. If loose, or if the heads are badly formed, cracked, eccentric to the shank or do not bear truly on the plate or bar, rivets, are to be cut out and replaced. All surfaces to be riveted must be in close contact throughout.

307. PLUMBING AND DRAINAGE

307.1 GENERAL

307.1.1 Scope of works

Work under this Section shall encompass the supply and installation of the following:

1. Sanitary fixtures including water heaters, valves and fittings, booster sets
2. Water distribution and supply system
3. Waste water drainage system from sanitary installations
4. Storm water drainage system.

Sanitary fixtures shall be complete and include labor, supply and installation of all pipes and their supports, connections to existing pipes or to sanitary fixtures, valves, accessories, as well as fixing, excavation and backfilling works required for the piercing and repair of walls, slabs and ceilings, and this, according to the drawings and the specifications of this Section.

307.1.2 Non restrictive list of works provided for in this Section

- Cold water distribution to sanitary installations and intakes
- Hot water distribution to sanitary installations
- Drainage of waste water and storm water to sewers or septic tanks
- Execution of primary ventilations
- Supply and installation of all floor drains
- Sanitary fixtures
- Waste water lifting systems
- Sinks
- Openings in partition walls and masonry
- Plugging up openings left in concrete surfaces after pipelaying
- Equipotential connections
- Branching of all fixtures
- Operation tests.

307.1.3 Contract documents

Nota: The list of texts mentioned hereunder is not restrictive. Works should be consistent with all texts in force at the time of their execution.

Plumbing

1) Unified Technical Documents (DTU)

1.1	Sanitary plumbing for dwellings (DTU P40-201)	
	Tender document	October 1959
	Chapter IV of tender document	November 1981
	Supplement N° 1: Installation of inserts in floors and walls	July/August 1969
	Supplement N° 4: Steel pipes for water distribution inside buildings	
	Particular specifications document and Memento thereto	January/February 1977

	Supplement N° 5 modifying supplement N° 4: Steel pipes for water distribution inside buildings	December 1979
	Erratum	April 1980
1.2	Cast iron pipes for waste water, storm water and sewage drainage (DTU P41-220) Technical Specifications Document	July 1984
1.3	Calculation rules for sanitary plumbing installations and storm water drainage installations (DTU P40-202)	October 1988
	Unplasticized P.V.C pipes	
1.4	Storm water drainage (DTU P41-212) Tender document	November 1981
1.5	Waste water and sewage drainage (DTU P41-213) Tender document	November 1981

1.6 CIBSE Guide B8: Sanitation and waste disposal 1972

1.7 Code of practice CP3; Engineering and utility services

1.8 Code of practice CP304; 1968 Sanitary pipework above ground

1.9 Code of practice CP301; 1971 Building drainage

1.10 Code of practice CP305; Sanitary appliances

1.11 Code of practice CP308; 1974 Drainage of roofs and paved areas

1.12 The uniform plumbing code for housing

1.13 Plumbing manual

1.14 National plumbing code

2) Standards

French standards; NF class:
- A pipes
- D fixtures
- E valves and fittings - connections
- P sanitary plumbing
- T PVC

Simple faucet of sanitary fixture - Vocabulary	NF D 18-001
Sanitary valves and fittings - Simple faucets and washer type mixers - General technical specifications	NF D 18-201
Mechanical washerless mixers - General technical specifications	NF D 18-202
Valves and fittings - globe valves used as isolating valves - terminology specific to valves and fittings installed in buildings	NF E 29-064
Hot or cold water distribution (terminology)	NF P 41-101
Waste water drainage (terminology)	NF P 41-102
Code of the minimum conditions for the execution of plumbing works and urban sanitary installations	NF P 41-201

Globe valves used as isolating valves - General technical specifications	NF P 43-001
Water pressure reducers - General specifications	NF P 43-006
Globe valves used as intake valves - General technical specifications	NF P 43-015

British standards; BS class

Cast Iron Spigot and Socket Drain Pipes and Fittings, Part 1: Pipes, Bends, Branches and Access Fittings.	B.S.	437
Concrete Cylindrical Pipes and Fittings, Including Manholes, Inspection Chambers and Street Gullies. Part 2: Metric Units	B.S.	556
Schedule of Cast Iron Drain Fittings, Spigot and Socket Type, for use with Drain Pipes to B.S. 437	B.S.	1130
Steel Tubes and Tubulars Suitable for screwing to B.S. 21 Pipe Threads	B.S.	1387
Asbestos-Cement Pipes, Joints and Fittings for Sewerage and Drainage.	B.S.	3656
Unplasticized P.V.C. Soil and Ventilating Pipe, Fittings and Accessories.	B.S.	4514
Prestressed Concrete Pipes for Drainage and Sewerage.	B.S.	5178
Specification for Unplasticized P.V.C. Pipe and Fittings for Gravity Sewers.	B.S.	5481
Cast manhole covers, graings, gullys, etc	B.S.	497

307.1.4 Openings in concrete surfaces and repair works

The Contractor shall bear the costs of labor and supply of materials required for the execution of openings and reinstatement of masonry and/or concrete works, as well as for preliminary or complementary works pertaining to sanitary installations, regardless of the difficulty of such works. No piercing in load-bearing structures (columns, beams, ...) shall be allowed unless so approved by the Engineer. Openings and storm water drainage system shall be carried out in accordance with Sections: waterproofing of New Works and Concrete Works.

307.1.5 Cleaning and protection

The Contractor shall be responsible for the protection of all sanitary fixtures from any damage and until the taking over of works.

All openings in the slab shall be sealed and protected. Floor drains shall be covered. Pipes free ends shall be protected against the intrusion of foreign bodies. The use of new sanitary fixtures throughout the works shall not be allowed.

Openings in roofs for storm water drainage shall be consistent with Waterproofing of New Works and Concrete Works. On completion, all fixtures and accessories shall be cleaned and polished.

Prior to taking over, the Contractor shall clean all the installation and purge all piping systems in order to ensure that they are free of wastes. In case pipes are plugged, the Contractor shall clean them and put them into service at his own expense.

307.2 PIPES AND FITTINGS

307.2.1 Application

Water pipes external to the buildings (i.e. undergound) shall be galvanized steel, threaded, in accordance with DIN 2440, medium duty or equivalent. (BS 1387).

Hot, cold and potable water pipes inside buildings shall be copper solder type to BS 2871 table X exposed and painted to Engineer requirement.

Waste water drainage pipes inside toilets shall be PVC according to DIN 19531 or UPVC to BS 4514.

Waste water drainage pipes underground shall be UPVC according to BS 4660 or equivalent.

Storm water drainage pipes inside shafts and between external manholes shall be of PVC according to DIN 19534, heavy duty or equivalent.

Storm water drainage pipes built-in walls shall be of PVC according to DIN 19531, heavy duty or equivalent.

Storm water drainage pipes between external manholes shall be of PVC according to DIN 19534, heavy duty or equivalent.

307.2.2 Galvanized steel pipes

307.2.2.1 Jointing of pipes

Pipes shall be gas threaded, WHITWORTH system; it shall bear at least 2 times the maximum pressure. Pipe threading shall be done with a screwing-stock without a ratchet, and shall stretch over 18 to 20 mm approximately.

No bending of pipes shall be permitted. Jointing by welding shall be prohibited. Jointing and connection works shall only be carried out by means of tees, elbows, couplings, hammer lug unions and flanges.

The seal of joints shall be ensured by a hemp tow coated with ceruse or linseed oil or an equivalent tape. Couplings shall have protruding rims to prevent ovalization due to vice tightening. Joints (elbows, tees, coupling, nipples, hammer lug unions, etc ...) shall be of a known trademark: A.F.L or G.F. or the like. Joints shall be reduced in factory and not by means of reducing couplings.

Pipes shall be connected to the equipment or valves by means of hammer lug unions. Hammer lug unions or flanges shall be mounted on the pipes in judiciously chosen locations so as to facilitate the assembling and dismantling of a section of the distribution network.

307.2.2.2 Pipes fixing

Exposed pipes laid under a ceiling, on roofs and inside shafts shall be fixed on iron, U stay-rods and struts by means of rigid fixing collars.

U struts shall be clamped to the ceiling with two rods threaded at both ends. The upper end shall be inserted in a “read head” type female socket embedded in the slab. The lower end of the rod shall support the strut by means of a nut.

The number of supports shall be sufficient to avoid deflection, shocks, expansion, etc ...

Spacing between supports and the diameter of bearing rods depends on the pipe diameter.

Pipes	1/2″, 3/4″, 1″	1 1/4″, 1 1/2″, 2″	2 1/2″, 3″, 4″
Spacing	1.5 m	2.25 m	3 m
Diameter of the rod	12 mm	12 mm	12 mm

307.2.2.3 Sleeves

Walls and slabs penetrations shall be through steel sleeves embedded in the cement, allowing the free expansion of pipes.

The sleeves diameters shall be determined with due regard to the pipes diameters so as to insert an isolating plastic between the steel sleeve and the metal pipe whenever used.

Sleeves shall receive an inside and outside rustproof protection and shall be built-in in masonry prior to pipe installation.

Measures shall be taken to avoid dust projection and noise transmission through the sleeves from one room to the other.

307.2.2.4 Finishing and protection

Pipes embedded in masonry shall receive a cathodic protection by means of 3M plastic adhesive tape or Denso tapes or any approved equivalent. The tape shall be regularly applied to cover the entire pipe.

Threaded pipes shall be protected with an oil or graphite coating or any other equivalent to ensure total watertightness. Exposed water pipes shall be isolated with a 25 mm thick fibreglass.

Protruding pipes and their supports shall be coated with an anti-corrosion paint of an approved colour.

307.2.2.5 PVC drainage pipes

All material, pipes and fittings, various connections, tees, elbows, reducing couplings, O rings shall be of a European trademark.

307.2.2.6 Thickness of pipes

Thickness of pipes shall be to DIN 19531 or DIN 19534 or equivalent as follows:

1- Standard pipes to DIN 19531:

Diameter 1 1/2″	thickness 1.8 mm
Diameter 2″	thickness 1.8 mm
Diameter 3″	thickness 1.8 mm
Diameter 4″	thickness 2.2 mm

2- Heavy duty pipes to DIN 19534:

Diameter 4″	thickness 3 mm
Diameter 5″	thickness 3 mm
Diameter 6″	thickness 4.5 mm

307.2.2.7 Mounting, fixing and finishing works

Heavy duty pipes shall be jointed with O rings, and standard pipes with glued joints to the satisfaction of the manufacturer.

Pipes shall be cut with a saw. Male ends of sawn pipes shall be trimmed and beveled prior to jointing. Technical specifications of the manufacturer shall be observed. Inaccessible jointings shall be glued.

Storm water pipes crossing false columns or embedded in concrete shall be covered, prior to concrete placing, with corrugated cardboard which shall be well compacted around the pipe up to a uniform thickness of 2.5 cm minimum.

Crossing of partition walls load-bearing, walls, floors shall be through a sleeve having a diameter roughly larger than that of the pipe.

Exposed pipes shall be fixed by means of U rods as specified for galvanized pipes.

307.2.3 Pipe laying

Pipelaying shall be to D.T.U. 60.1.

Main lines shall be laid exposed at low-level or in false ceilings wherever existing. Branchings connected to fixtures shall be carried out exposed unless otherwise instructed by the Engineer.

Pipes and fittings shall have as much as possible vertical and horizontal routes and allow the free flow of water from and to all installations and fixtures.

Horizontal pipes shall have the following slopes, unless otherwise provided for by the Engineer:

Water supply pipes	0.5 to 1%
Waste water drainage pipes inside toilets	2%
Waste water and stormwater drainage pipes, buried or laid inside false ceilings	1%

Cleanouts, even where not specifically called for shall be installed at each change of direction in storm and waste water pipes.

Prior to jointing pipes, they shall be thoroughly cleaned so as to ensure the total absence of any foreign body.

Pipes having different diameters shall be jointed by means of eccentric reducers.

Except for pipes crossing masonry, all protruding pipes shall be kept 3 cm clear from vertical walls, slabs, ceilings and any other pipelines. However, the distance between such pipes and floors shall be 5 cm. Protruding or built-in pipes shall be accessible all along their route in order to facilitate inspection, maintenance or eventual modifications.

Automatic drain traps shall be mounted at high points of pressure water pipes.

To allow free expansion, the distribution network shall be so arranged as to move occurring expansions towards compensating devices. The latter shall be mounted by the Contractor although not specified on the drawings.

307.2.4 Pipe insulation

307.2.4.1 General requirements

- Insulation shall be carried out neatly and to a high standard by skilled workers, experienced in the trade.
- The thermal insulation shall be non-corrosive to the metal, water repellant and fire retardant.
- All metal surfaces shall be thoroughly cleaned and treated with approved corrosion inhibitor before applying insulation. Inhibitor coating would not be required for galvaniazed surfaces.

- Strainers, valves (size 80 mm and above) and other fittings which require opening for maintenance/repairs shall be provided with insulated boxes.

- All openings in roof slabs and walls for passing pipes should be suitably weather proofed. Metal sleeves should be provided where pipes pass through masonary walls or partitions. All openings in roof, ceiling or walls made for the purpose installation shall be sealed to prevent ingress of rodents, insects, dust, moisture and water. Opening in equipment casings shall be sealed likewise.

- All pipe insulation shall be covered with cotton canvas/fiberglass cloth and vapour sealed. The cloth shall be soaked in approved weather proofing compound and wrapped careffuly to provide a smooth surface, free from wrinkles and gaps. There should be at least 50 mm overlap at transverse and longitudinal cloth joints. Second coat of vapour seal shall be applied after drying of the first coat. This vapour barrier finish shall be carried over the load bearing inserts at location of supports or hangers without discontinuity or punctures.

- The vapour seal material shall be fire resistant, non-toxic, weather resistant and anti-fungus quality. Bitumen based products shall not be used.

307.2.4.2 Hot water pipe insulation

- All hot water pipes are to be insulated with rigid fibreglass sections of density not less than 96 kg/m^3, thickness of insulation shall be 25 mm. minimum, or 19 mm thick foam rubber.

  Higher thickness of insulation shall be used, for large pipes and headers, if specified.

  Performed sections of other insulation materials (except expanded polystyrene) may be specified subject to the considerations of safety, hygiene and finish and subject to the prior approval of Engineer.

- Threated hardwood rings or approved plastic inserts shall be provided between the pipes and supports.

- Aluminum cladding shall be provided for mechanical protection over insulated and vapour sealed exposed hot water pipes in plant rooms upto a height of 2.2 m from floor level and in the boiler room.

307.3 WATER SUPPLY VALVES AND FITTINGS

307.3.1 General

All necessary valves and fittings, required for the installation of sanitary fixtures according to the drawings and the following specifications, shall be supplied and installed.

Gate valves shall be used to isolate and cut off water from main lines or branchings. Washouts shall be installed at the foot of rising columns and at the low spots of water systems. They shall be ½” in diameter and have a male connection for flexible pipes or as shown on the drawings.

Threaded couplings valves shall be connected to the pipes and fittings by means of hammer lug unions.

Flanged valves shall be connected to the pipes and fittings by means of glands, joints and bolts; flanges and glands shall be drilled according to the standards of the country of origin.

Valves shall be installed to allow easy access and dismantling.

Working and tests pressures shall equal respectively 6 and 12 bars.

307.3.2 Check valves

Check valves shall be either of the swing or lift type. They shall be installed on horizontal or upward vertical pipes.

For diameters ≤ 2 ½″, the valves shall be bronze and fitted with tapped couplings. For diameters > 2 ½″, the valves shall be cast iron, fitted with flanges. Sealing surfaces and the hinge pin shall be of stainless steel.

307.3.3 Float valves

Float valves shall be of the swing handle type. The body and small handles shall be made of bronze, and the long handle of stainless steel.

The valve shall be made of durable and resistant plastic material or of rubber.

307.3.4 Automatic drain traps

They shall be fitted with a float that operates the air release mechanism.

The trap shall be supplied along with a stop valve, installed downstream of the trap and allowing the dismantling of the latter without need to empty the installation.

307.3.5 Surge suppression devices

Surge suppression devices shall be of stainless steel with an elastomer membrane for a working pressure of 10 bars with a ½″ pipe connection. They shall be of JOSAM trademark or any equivalent.

307.3.6 Slide valve

Slide valves ≤ 2″ in diameter shall be made entirely of bronze, with iron tubes thread, and fitted with an iron handwheel.

307.3.7 Gate Valve

Gate valves ≥ 2½″ in diameter shall have an iron body, fitted with glands and operated by an outside screw and yoke and a handwheel.

307.3.8 Globe Valve

Globe valves ≤ 2″ in diameter shall be made of bronze, with iron tubes thread and fitted with a replaceable disc of approved type.
Globe valves ≥ 2½″ in diameter shall have an iron body, fitted with glands and a replaceable bronze thrust plate of approved type.

307.4 DRAINAGE ACCESSORIES

307.4.1 Floor drains

Floor drains shall be PVC and of an approved European trademark.

Each floor drain shall have three 2″ inlets, and one 3″ horizontal outlet. It shall be equipped with a chromium bronze strainer screwed to the frame. The strainer’s dimensions and orientation shall comply with tiling constraints.

307.4.2 Balcony drains

Balcony drains shall be made of PVC and of an approved European trademark. They shall be fitted with a stainless steel plated strainer and have a horizontal outlet for connection beneath the tiles.

307.4.3 Roof drains

Roof drains are installed to discharge storm water of unused roofs. They shall be PVC made and of an approved European trademark.

Each drain shall comprise a drainage funnel and a strainer screwed to the top of the funnel embedded in the sealing material.

307.4.4 PVC inspection holes

PVC right-angled crosses, 4 inches in diameter, having 3 inlets and one outlet shall be used as inspection holes inside toilets.

One of the inlets shall be fitted with a completely tight chromium bronze cover, screwed to the frame and intended for cleaning.

307.4.5 Floor cleanouts

They shall consist of PVC 45° bend or a T or F connection with a completely tight door screwed to the frame.

307.4.6 On-line cleanouts

They shall all be of the same trademark as the pipe and provided with a bolt down door. They shall be installed at every 90° deviation.

307.4.7 Concrete manholes

Concrete manholes shall be constructed outside the building to collect waste and storm waters into two distinct networks. They shall be constructed at each change of direction or diameter of the drainage pipe and to the details shown on the drawings.

Storm water manholes shall be fitted with a cast iron grating fixed on a cast iron frame.

Waste water manholes shall be equipped with a cast iron watertight cover fixed on a cast iron frame.

The lower part of the manhole shall consist of a concrete slab proportioned at 350 kg of cement per 1 m^3 of gravel and 0.5 m^3 of sand.

It shall be rendered with a cement mortar (600 kg) to have a perfectly smooth surface showing no asperity likely to retain impurities.

The concrete walls of the manholes shall be 0.20 cm thick and made of precast elements or cast-in-place.

The outgoing pipes bottom shall line up the lowest level of the waste water manhole. The base slab of storm water manholes shall be, on the contrary, 5 cm deeper than the outgoing pipes level in order to retain leaves and waste.

The dimensions of the manhole vary with the depth as indicated hereinafter:

Depth	**Dimensions**
Down to 40 cm	40 × 40 cm
Down to 120 cm	60 × 60 cm
From 120 to 180 cm	100 × 100 cm
More than 180 cm	120 × 120 cm

307.4.8 Main ventilation column

The top of the main ventilation column shall be fitted with PVC ventilation hood mounted on roofs and kept as much as possible away from visited places. They shall be equipped with an insect proof screen.

307.5 SANITARY FIXTURES

307.5.1 General

All sanitary fixtures shall be submitted to the Engineer for approval and prior to ordering.

All sanitary fixtures shall be new, of the colour specified by the Engineer, of first grade quality and flawless. All visible accessories such as flushes, fittings, escutcheons, pipes and fixing nuts shall be made of shiny chromium - plated brass, and shall have smooth lines with no protruding parts.

All sanitary fixtures shall be set level and true allowing to make right angled connections with adjacent walls. Openings and holes shall be plugged carefully as to comply with the finishing material of walls and floor.

All visible chromium plated fittings, as well as stainless steel connections and accessories shall receive, directly after installation, a thick coat of protective petroleum gelatinous material.

Brackets, supports and embedded ironworks shall be coated in situ with an anti corrosion paint.

307.5.2 Washbasins

Washbasins shall be made of glazed porcelain and shall be complete with chromium-plated taps and washer type mixer, brackets, an angle valve, U-bend pipes, supply and waste piping, a soapdish, a towel rail, a mirror, a shelf and all other accessories.

Each branching for hot or cold shall not be less than ½”.

307.5.3 Water closets (seats)

Water closets shall be fitted with a 13 liters capacity flushing vessel and ½″ angle valve. No W.C. branching shall be less than ╛′.

Each branching for hot or cold shall not be less than ½”.

307.5.4 Sinks

Sinks shall be of stainless steel and shall incorporate the worktop. They shall be equipped with three chromium plated taps (hot, cold and drinking water), a strainer, a polypropylene trap, stop valves, supply and waste piping, fixing devices and all other accessories.

Each branching for hot or cold shall not be less than ½”.

307.5.5 Shower cabinet

Shower cabinets shall be of the built-in or surface mounted shower tray type measurements of $90 \times 90 \times 28$ cm^3. They shall include a shower head with variable direction, hot and cold water taps, a washer type mixer, connection and waste pipes and all other accessories.

Each branching for hot or cold shall not be less than ½”.

307.5.6 Urinals

Urinals shall be glazed porcelain wall mounted $43 \times 24 \times 47$ cm^3 with pressurized flushing, separated each 60 cm by adequate partition walls.

They shall be complete with a push-button faucet, chromium plated trap, supply and waste piping as well as all accessories.

Each branching for hot or cold shall not be less than ½”.

307.6 WASTE WATER DRAINAGE SYSTEM

307.6.1 General

The waste water drainage system shall be complete and consistent with the drawings and the specifications below. The system shall comprise manifolds of sanitary fixtures, drops, mains, ventilation pipes, inspection holes, manholes, the installation of sump pumps and their control mechanisms, accessories, suspensions, supports, fixings and all other required accessories necessary for the good functioning of the installations.

307.6.2 Piping

Pipes used for this system shall be consistent with the specifications of Waste water drainage pipes.

Unless otherwise indicated, the diameters of drainage pipes shall be as follows:

W.C.	4″
Sink, wash basin	2½″

Connections between drops and horizontal manifolds shall be through long radius elbows. Cleanouts shall be mounted at the foot of every drop, every change of direction, at the end of every branch as indicated on the drawings or required by the Engineer. They shall not be more than 15 m apart for 4″ horizontal manifolds, and 30 m maximum apart for those of a diameter exceeding 4″. Manifolds shall have a gradient of 1% in the flow direction unless otherwise specified.

307.7 GULLY TRAPS

Gully traps shall be of concrete or asbestos-cement, as shown on the Drawings. All internal surfaces of the gully traps shall be smooth and all edges rounded. The inside of concrete traps shall be plastered with cement mortar trowelled to a glossy surface. The trap seal shall be 5 cm minimum. The trap shall be placed on a concrete bedding at least 10 cm thick and shall be surrounded by concrete.

307.8 RAINWATER DISPOSAL

The rainwater disposal system shall be in accordance with the Drawings and/or as required in the Particular Specification.

Unless otherwise specified, the minimum diameter of leaders shall be 100 mm, except that for draining very small areas the Engineer may permit the installation of 75 mm dia. leaders. In any case the outlet of the leader shall be a 100 mm dia. bend. All leaders shall be installed in a straight line from the gutter to the outlet. If bends in a leader cannot be avoided, appropriate openings, easily accessible for cleaning, shall be provided on the bends. The top inlets of leaders shall be protected by stainless steel or galvanized wire strainers. The free outlets of leaders, where not connected to manholes of the storm water pipe system, shall terminate in 45° of 60° bends. The drain water shall drop onto a precast concrete dish diverting the water away from the foundations of the buildings.

307.9 SEPTIC TANK

307.9.1 General

Septic tanks shall be provided for small communities, and only whenever it is not possible to connect the sewerage system to a wastewater treatment facility. The tank shall be constructed in accordance with the drawings and/or as required in the Particular Specifications.

The septic tank shall achieve liquid-solid separation and shall provide digestion and storage of the settled organic solids.

307.9.2 Detailed Specifications

Septic tanks shall be designed and constructed in accordance with the following criteria:

a) A minimum hydraulic retention time of one day for the end of the design period average daily flow.

b) A minimum of one year production of sludge and scum storage capacity.

c) Design flow of 120 liter/capita/day shall be used in calculating the tank capacity.

d) Overall tank length shall be 2 to 3 times the tank width.

e) Water depth shall be between 1.2 m to 1.7 m. Minimum clearance between tank roof and liquid level shall be 0.3 m.

The septic tank is divided into two compartments with the first compartment having twice the volume of the second compartment. This arrangement shall ensure that the hydraulic load and the turbulence created by the incoming wastewater is absorbed in the first compartment. The second compartment shall achieve settlement for the low density solids since it receives the hydraulic load at a lower rate than does the first compartment.

The incoming wastewater shall enter the first compartment via a 200 mm ductile iron tee. The tee shall be designed and installed so as to dissipate the energy of the incoming water, to minimize turbulence, and to prevent short circuiting. The vertical leg of the inlet tee shall extend below the liquid surface to the specified level in accordance with the drawings.

The outlet of the first and second compartment shall be constructed in a manner so as to retain the sludge and scum formed in both compartments. The outlet of the first compartment is comprised of two (2) 200 mm dia elbows equally spaced along the width of the intercompartmental wall. The outlet of the second compartment is comprised of a one(1) 200 mm dia tee. The outlets shall have the submergence and height above the liquid level in accordance with the drawings.

A gas deflection baffle shall be provided underneath the outlets to prevent the entrance of gas disturbed sludge in the rising leg of the outlets.

307.9.3 Venting Provisions

The septic tank shall be vented to allow for the escape of accumulated methane, hydrogen sulfide, and other gases produced from digestion of the settled solids.

A 200 mm vent pipe shall be constructed on top of the second compartment and shall extend 3m above the finished grade level. Gases formed in the first compartment shall be vented to the second compartment via two 100 mm dia openings in the intercompartmental wall. The two openings shall be located above the scum level in accordance with the drawings.

307.9.4 Access Manholes

Two manholes with cast iron covers shall be provided over the inlet and final outlet pipes. The manholes shall provide access and means to inspect the inside of both compartments. The manholes shall also be used whenever tank desludging is required. The manhole covers shall be fitted with gaskets to provide a weather proof seal. Two each 300 mm inspection pipes with removable covers shall be provided on top of the first compartment outlets pipes.

307.9.5 Structure of the septic tank

External walls of the precast or cast-in-place septic tank shall have a nominal thickness of 25cm; the partition walls between the tank’s compartments shall be 20 cm thick.

Each vertical wall shall be reinforced with two layers of high yield steel bars installed at the rate of 6 HA 14/m in both directions and on both sides. Bars shall be kept 4 cm clear from the formwork.

The base slab shall be connected to the upper slab by bending the bars in such a way as to ensure a 50 cm penetration into each of the slabs.

The upper slab shall be 25 cm thick for tanks 2 m wide.

The base slab of the tanks shall be 25 cm thick, and shall extend a distance of 15 cm, from both sides of the tank walls. It shall be laid on a 10 cm thick concrete blinding layer.

Following are the concrete mix design:

- Base slab, upper slab and vertical walls: 350 kg of supersulphated portland cement (CLK) for 400 liters of sand and 800 liters of fine gravels

Generally, hydrostatic tests shall be conducted on the pipes before they are connected to fixtures.

In no case shall the pressure tests of pipes, equipment, etc ... exceed the working pressure of such pipes, equipment, etc ... Prior to and upon completion of tests, all equipment, piping, strainers, etc ... shall be thoroughly cleaned and put into working order.

307.10 MISCELLANEOUS DEVICES

307.10.1 Domestic water reservoirs

Domestic water reservoirs shall be made of 4 mm thick polyethylene and suitable for drinking water storage.

The reservoir shall resist ultra violet radiations and support without showing any deflection whatsoever, a temperature equal to 70° C.

It shall be manufactured to FDA21 - CFR 177, 1526 or equivalent.

The capacity shall be indicated on the drawing (> 1000 liters). All necessary accessories for the good functioning of the reservoirs shall be provided.

307.10.2 Electric water heater

Electric water heaters shall be installed according to the drawings. They shall be of the wall mounted or under sink installed type. They shall have an enamelled tank and shall be fitted with an automatic drain trap, a safety valve and all necessary accessories (heating element, adjustable thermostat, thermal insulation, ...).

Water heater shall be capable of heating the water capacity mentioned on the drawings to 80°C.

307.11 PAINTS

Work under this Section include the following:

Prior to any insulation metal pipes and reservoirs shall be wire brushed and coated with a bituminous or rustproof paint. Exposed covers and covered equipment shall receive a primer and a finish paint.

Reservoirs shall be lined and coated with 2 layers of rustproof paint.

307.12 TESTING

Each test report shall contain the following minimum information:

- The nature, hour and place of the tests
- The adopted procedure
- Means, material and labor
- The results.

Watertightness and mechanical strength tests of supply pipes and their accessories shall be carried out prior to painting.

Before conducting any test, a thorough cleaning of the whole installation shall be carried out.

Sections of pipes shall be isolated in order to carry out tests thereon under the required pressure.

A hydrostatic test shall be carried out at a pressure of 9 bars that is 1.5 times the maximum working pressure in order to check out:

- The valves mechanical strength
- The watertightness of pipes and their accessories.

The test pressure shall be maintained for 24 hours. Should the pressure tests be unsatisfactory, the Contractor shall search for and make good all defects causing leakages. After repairs, the installation shall be retested until it satisfactorily passes the test. Upon completion of the watertightness test, another test under the maximum working pressure shall be conducted. The pressure shall be maintained unchanged for 12 hours.

The watertightness test of waste water drainage pipes shall be conducted using a smoke cartridge that produces a smoke volume superior to that of the tested pipes.

Ventholes shall not be plugged before smoke has come out through their whole sections. No joint shall show any smoke leak.

In the case of unavailability of appropriate material required for tests using smoke, hydrostatic tests under a 0.2 kg/cm^2 test pressure shall be carried out after having closed all the outlets and have purged all pipes.

All waste and storm water drainage system shall be subjected to a pressure test of 5 meters of water. The hydrostatic pressure of the test shall be maintained for two hours without the system showing any leak or drop in pressure.

308. FIRE FIGHTING

Portable type fire extinguishers shall be provided as detailed in the Particular Specifications.

The following types of Portable fire extinguishers are used:

All Portable fire extinguishers shall be in accordance with American regulations standard 10-1 and or equivalent European and internationally accepted standards such as BS 6535, 6643 and 5423.

– CO_2 type fire extinguisher (G) of 6 kg complete with hose, H Horn and wall mounting bracket.

– ABCE Powder type fire extinguisher (P) of 12 Kg complete with wall mounting brackets.

– ABCE Powder type on wheels fire extinguisher (PW) of 35 Kg.

– Cylinders shall be of 1.5 mm stamped iron plate of high quality, electric welding under electronic control, red oven painting with epoxy powders, and bursting pressure tested till 80 bars.

– Valves shall conform to European newest standards in stamped brass with safety device.

– Manometer of good quality.

– Rubber hose with working pressure of 20 bar.

– Dry nitrogen propeller.

– Temperature stability -60ºC + 80ºC

– Powder shall be of non toxic during handling and applications and shall be dry and durable for at least 5 years.

309. HEATING VENTILATION & AIR-CONDITIONING

309.1 GENERAL

309.1.1 Technical clauses

Equipment and material shall be of good quality and stored under the best conditions (protected from temperature, sunlight, corrosion...). They shall be stored and sheltered from adverse weather conditions, such as humidity and temperature variations, dirt and dust, or other contaminants.

Transport costs shall be borne by the Contractor. Before ordering, he shall submit samples and catalogues for approval. Equipment shall be installed taking into consideration the manufacturer recommendations to ensure proper access, operation, and maintenance.

Subject to approvals, shop drawings may be modified to meet the requirements of the manufacturer. Materials which are not approved or found not easily accessible for maintenance shall be rejected, replaced and reinstated by the Contractor at his own expense.

309.1.2 Civil works

The Contractor shall be responsible for the coordination of all requirements of other Sections works namely, those of civil engineering and electricity, regarding the provision of openings in masonry or concrete works. In default, he shall perform upon the approval of the Engineer, all piercing, fixing and closing works. Where the Engineer refuses any such work, the Contractor shall not have right to claim for indemnity. Before closing the openings, all ducts, shafts and sleeves shall be covered with an approved resilient material.

309.1.3 Nameplates

Equipment shall have a nameplate that identifies the manufacturer’s name, address, type or style, model or serial number, and catalog number.

309.2 DESIGN CRITERIA

309.2.1 Design conditions

Outside conditions in summer:

92° F (33° C) Dry-bulb temperature
82° F (28° C) Wet-bulb temperature
Inside conditions in summer:

75° F (24° C) Dry-bulb temperature
50% Relative humidity

Outside conditions in winter

40° F (4° C) Dry-bulb temperature

Inside conditions in winter

68° F (20° C) Dry-bulb temperature

The noise level from evaporation machines and air extractor, measured at 1.5 m from any grille should not exceed 40 dBA.

Where this level is exceeded, sound attenuators shall be installed by the Contractor at his own expense.

Windows shall be 6 mm thick single-glazed or double glazed as per the project requirements.

309.2.2 Design cooling capacities

Air Cooled A/C equipment must give the required duty when the air temperature entering the condenser is equal to the specified design outside summer dry bulb temperature unless the specifications call for higher temperature for special applications. In addition, the equipment shall continue to function satisfactorily withou tripping or overheating at a maximum outside dry bulb temperature 40° C.

309.2.3 Accepted standards

The following standards are accepted for ACHVR services provided that necessary corrections and provisions are made to suit local climatological and design conditions, power supply system and other required codes.
ASHRAE: American Society of Heating Refrigeration and Air Conditioning Engineers (U.S.A)

IHVE : The Institute of Heating and Ventilation Engineers (U.K.)
ASME : American Society of Mechanical Engineers.
ARI : Air Conditioning Refrigeration Institute (U.S.A.)
ASTM : American Society for Testing and Materials.
AWS : American Welding Society.
UL : Underwriter Laboratories (U.S.A.)
SMACNA: Sheet Metal and Airconditioning Contractors National Association, Vienna.
HVCA : Heating and Ventilation Contractor’s Association, U.K.

ADC 1062:GRD (1984) Test Codes for Grilles, Registers and Diffusers

AIR MOVEMENT AND CONTROL ASSOCIATION (AMCA)

AMCA 210 (1985) Laboratory Methods of Testing Fans for Rating

AMCA 300 (1985; REV 1987; errata) Reverberant Room Method for Sound Testing of Fans

ASTMD1654 (1992) Evaluation of Painted or Coated Specimens Subjected to

	Corrosive Environments
ASHRAE 52	(1968; R 1976) Air-cleaning Devices Used in General Ventilation for removing Particulate Matter
ASHRAE 68	(1986) Laboratory Method of Testing

Other International Standards may be considered provided they meet with the above standards as a minimum.

309.3 EQUIPMENT AND INSTALLATION

309.3.1 Split system heat pump

309.3.1.1 General

Air conditioners shall be of split system heat pumps type. The evaporators shall be installed on the mezzanine and/or on the roof. Condenser units shall be roof mounted.

309.3.1.2 Evaporator

It shall include:

- Heat exchanger with copper tubes and aluminium fins tested under 21 bars at the factory
- Expansion valve
- Balanced centrifugal fan, multi-speed installed on life-greased bearings
- washable metalic 25 mm thick filter, 90% arrestance of all particles down to 3 microns with an outside lable indicating danger of inflammability.
- Insulated stainless steel drain tray (sloped toward drain pipe) to receive condensates.

The system shall be installed in a metallic casing of thick sheet steel protected with two coats of baked paint and internally lined with fibreglass of suitable thickness.

309.3.1.3 Condensing unit

It shall include:

- Hermetic compressor with stop valve at the suction and the discharge, mounted on antivibration pads in a technical enclosure. The compressor shall be of gas suction cooled type

- Condenser coil made of drawn copper tubes, with aluminium fins and a liquid line solenoid valve. Aluminium fins shall be treated by cataphoresis: scouring, rinsing, deoxydation then rinsing, phosphate crystal coating, bonderising, black or grey electrolytic cataphoresis paint, ultra filtering rinsing with demineralized water

- Expansion valve

- Fan with protection grille

– Shock resistant bottle.

The assembly shall be installed in a perforated casing. The metal jacket shall be of galvanized sheet treated with phosphate, and of suitable thickness. It shall be protected with two coats of baked paint.

Motors winding shall be thermally and electrically protected and weatherproof.

Control circuit shall include a time-delay relay and an electric protection for the compressor, a phase failure detector (loss of one phase or reverse phasing) for the three-phase motor, high and low pressure switches, a relay for the fan and a relay for the evaporator.

309.3.1.4 Refrigerant pipes

Refrigerant pipes between the evaporation and the condenser shall be hard copper, L type, insulated with Isoflex expanded synthetic rubber. Refrigerant pipes shall be soldered by nitrogen. Length of refrigerant pipes shall be carefully selected in relation with the units.

309.3.1.5 Control and electric connection

Cables and electric equipment shall be installed as specified in their relevant sections.

Control and electric connections shall include:

- A seasonal winter/summer thermostat with a selector switch: ON-OFF-VENTILATION. Thermostat shall be of remote bulbs type
- A circuit-breaker
- A control circuit between the evaporator and the condensing unit. Control cables shall be multicores, NYM type or equivalent
- All equipment shall be fitted with double insulated transformer allowing supply of the control circuit. The main power supply shall be three-phase. The Contractor shall be responsible for the installation of electric cables starting from the circuit breaker.

309.3.1.6 Installation

The evaporator shall be mounted on neoprene anti-vibration pads installed on U bars secured to the ceiling.

The condenser shall be mounted on neoprene anti-vibration pads. The drain pipe shall be PVC with a P-trap with 50 mm high waterseal.

The blower shall be connected to the duct by a 20 cm wide thick flexible duct.

Blower noise level shall not exceed 40 dBA when measured at a distance of 1 meter from the supply and return grilles. Blowers shall be fitted at the discharge with sound attenuators.

Roof-mounted evaporators shall be installed in a 150 cm high room. The room will house all supply and return ducts. Openings of supply and return ducts in the roof slab shall be accessible and weatherproof.

Free surface as per manufacturers recommendations shall be arranged around the evaporator for maintenance.

Waterproofing shall be ensured around ducts with metallic filler band.

309.3.2 Decorative air conditioners

309.3.2.1 General

Decorative air conditioners shall be of split system heat pump type. Evaporators and condensing units shall be wall mounted.

309.3.2.2 Evaporator

It shall include:

- Heat exchanger with copper tubes and aluminium fins tested under 21 bars at the factory

- Fan with tangential turbine with directional radial flow. Motor shall be of the silent type mounted on elastic suspensions and fitted with internal protections

- Air cartridge filter mounted on sliding guides and accessible from the front panel: 90% arrestance of all particules down to 3 microns

- Supply grille consisting of an adjustable multi-directional deflector

- Insulated stainless sheet steel drain tray to receive condensates

The casing shall have a polystyrene front and a stove enamelled steel backplate.

309.3.2.3 Condensing unit

The condensing unit will house the refrigerant compressor, the condenser, the moto-fan group, the expansion valve, as well as the electrical equipment.

- A hermetic compressor, mounted on antivibration pads in a technical compartment, fitted with a shock resistant bottle of gas suction cooled type. Stop valves shall be placed at the suction and at the discharge.

- A condenser coil made of drawn copper tubes with aluminium fins and fitted with a liquid liner solenoid valve.
  Aluminium fins shall be treated by cataphoresis: scouring, rinsing, deoxydation then rinsing, phosphate coating, bonderising, black or grey electrolytic cataphoresis paint, ultra filtering rinsing with demineralized water.

- A helicoidal fan with axial flow and low rotating speed and fitted with a protection grille, a motor of the silent type and shall be thermally and electrically protected.

- The casing shall be weatherproof and the compressor shall be placed in a soundproof compartment.

- Control circuit shall always include high and low pressure cutout switches, a relay for the fan, a relay for the evaporator and a time-delay relay for the compressor.

309.3.2.4 Refrigerant pipes

Refrigerant pipes between condensing unit and evaporator shall be precharged and delivered with the unit.

Refrigerant pipes shall have ends fitted with automatic wedge coupling. Length of refrigerant pipes shall be considered when selecting the units.

309.3.2.5 Control and electric connection

Cables and electric equipment shall be installed as specified in the relevant Seciton “Electrical Installations”.

Control and electric connections shall include:

- A seasonal summer / winter thermostat with a selector switch: ON-OFF-VENTILATION-COLD-HOT

- A three position velocity controller

- A circuit-breaker

- A control circuit between the evaporator and the condensing unit. Control cables shall be multicore, NYM type or equivalent

- Equipment shall be fitted with a double insulated transformer for the supply of the control circuit

- The main power supply shall be single-phase

- The Contractor shall be responsible for the installation of electric cables starting from the circuit-breaker.

309.3.2.6 Installation

The condensing unit shall be installed on neoprene antivibration pads and supported by a metal frame.

PVC drain pipes shall be used.

Operating noise level of evaporator shall not exceed 40 dBA when measured at a distance of 1 meter from the unit.

309.3.3 Roof top packaged A/C unit

309.3.3.1 General

The units shall be of the horizontal airflow with 40° C and 4°C in cooling as standard from the factory for all units. Cooling performance shall be as shown on drawings. All units shall be factory assembled, internally wired, fully charged with R-22 and 100 percent run tested to check cooling operation, fan and blower rotation and control sequence, before leaving the factory. Wiring internal to the unit shall be colored and numbered for simplified identification.

309.3.3.2 Casing

Unit casing shall be constructed of zinc coated, heavy gauge, galvanized stee. All components shall be mounted in a weather resistant steel cabinet with a painted exterior. Cabinet construction shall allow for all maintenance on one side of the unit. Service panels shall have lifting handles and shall be easily removed and reinstalled providing a water and air tight seal. The indoor air section shall be completely insulated with fire resistant permanent, odorless glass fiber material. The base of the unit shall have provisions for forkliff and crage lifting.

309.3.3.3 Filters

Two inches metalic washable filters on filter rack.

309.3.3.4 Compressors

A minimum of two compressors, shall be direct drive hermetic, reciprocating type with separate centrifugal oil pump providing positive lubrication to moving parts, motors shall be suction gas-cooled and shall have a voltage utilization range of plus or minus 10 percent of unit nameplate voltage. Crankcase heater, internal temperature and current-sensitive motor overloads shall be included for maximum protection. Compressors shall have internal spring isolation and sound muffling to minimize vibration transmission and noise. External high pressure cutout, discharge temperature limit, winding temperature limit and compressor overload shall be provided.

309.3.3.5 Refrigerant Circuits

Two independant refrigerant circuit each shall have independent fixed orifice expansion devices, service pressure ports and refrigerant line filter driers factor installed as standard. An area shall be provided for replacement suction line driers.

309.3.3.6 Evaporator and Condenser Coils

internally finned 3/8” copper tubes mechanically bonded to configured aluminum plate fin shall be standard. Coils shall be leak tested at the factory to ensure the pressure integrity. The evaporator coil and condenser coil shall be leak tested to 200 psig and pressure tested to 450 psig.

309.3.3.7 Outdoor fans

The outdoor fans shall be direct drive statically and dynamically balanced, draw through in the vertical discharge position. The fan motor(s) shall be permanently lubricated and have built-in thermal overload protection.

309.3.3.8 Indoor fan

Units shall have belt driven, FC centrifugal fans with adjustable motor sheaves and adjustment of fan belts and motor sheaves. All motors shall be thermally protected units shall be capable of providing 1” esp at nominal unit cfm.

309.3.3.9 Controls

Unit shall be completely factory wired with necessary controls and contactor pressure lugs or terminal block for power wiring. Units shall provide an external location for mounting fused disconnect device. Microprocessor controls shall be provided for all 24 volt control functions. The resident control unit shall make all cooling and/or ventilating decisions in response to electronic signals from sensors measuring indoor and outdoor temperatures. The control unit maintains accurate temperature control, minimizes drift from set point and provides better building comfort. A centralized Microprocessor shall provide anti-short cycle timing and time delay between compressors to provide a higher level of machine protection.

309.3.3.10 Electric heaters

Electric heat modules shall be available for installation within basic unit. Electric heater elements shall be constructed of heavy-duty nickel chromium elements internally wye connected for 400 volt. Staging shall be achieved through the unitary control processor (3 stages). Each heater package shall have automatically reset high limit control operating through heating element contactors. All heaters shall be individually fused from factory. The unit shall be equiped with a remote type control box installed as shown on drawings at 1.5 m above flow level having a thermostat. OFF/FAN/COOL and speed selection switch.

309.3.4 Electric convector heaters

Electric convector heaters shall be suitable for domestic and commercial application and shall be fabricated from a self-extinguishing material. They shall be fan assisted and suitable for wall or floor mounting. They shall be protected by a thermal overload device. Their controls shall include a 24 hour timer, frost thermostat (4^{o}C) and variable heat settings.

309.4 AIR FANS

309.4.1 General

Fans shall be tested and rated according to AMCA 210. Fans may be connected to the motors either directly or indirectly with V-belt drive. V-belt drives shall be designed for not less than 150 percent of the connected driving capacity. Motor sheaves shall be fixed pitch as defined by ARI Guideline D. When fixed pitch sheaves are furnished, a replaceable sheave shall be provided when needed to achieve system air balance. Motors for V-belt drives shall be provided with adjustable rails or bases. Removable metal guards shall be provided for all exposed V-belt drives, and speed-test openings shall be provided at the center of all rotating shafts. Fans shall be provided with personnel screens or guards on both suction and supply ends, except that the screens need not be provided, unless otherwise indicated, where ducts are connected to the fan. Fan and motor assemblies shall be provided with vibration-isolation supports or mountings. Vibration-isolation units shall be standard products with published loading ratings. Each fan shall be selected to produce the capacity required at the fan static pressure indicated. Sound power level shall be as indicated. The sound power level values shall be obtained according to AMCA 300. Standard AMCA arrangement, rotation, and discharge shall be as indicated.

309.4.2 Axial Duct Mounted Fans

309.4.2.1 General

Fan Casing shall be cylindrical in construction, with matching metric spirally wound ductwork. Manufactured in heavy gauge galvanized steel with corrosion resistant fixings used throughout. Flanges to be quickfit type.

309.4.2.2 Fan/Motor assembly

Impeller to be of high performance aerofoil type comprising a cast aluminum hub with either aluminum alloy or polypropylene blades. Motors to be manufactured to BS 5000 with class F insulation and sealed for life bearings. Motors to be pre-wired to an external terminal base through flexible conduit.

309.4.2.3 Accessories

Unit to be complete with two mounting pads, four adjustable feet, foot fixings, two quickfit matching flanges and single bolt self sealing clamping collars, two flexible connectors, matching electronic speed controller, pair of wall mounting brackets, inlet cone and wire guard, antibackdraught damper, converter from quickfit to bolted flanges.

309.4.3 Centrifugal In Line Duct Mounted Fans

309.4.3.1 General

Fan Casing shall be rectangular In sections, manufactured from galvanized steel to BS 2982 1982, of rigid constructions with cut edges turned inward for safety. Circular ruged spigots shall be fitted to both ends of the case. The unit shall be supplied with easy installations fixing brackets attached to the unit by means of a single set screw.

309.4.3.2 Fan/Motor assembly

The Fan assemblies shall in coorporate a directly driven, backward curved centrifugal impellers, powered by single phase 200-240 V 50 HZ motors, and balanced with VDI 2060 class Q2.5 to give quiet and vibration free running. Motor shall be rated for IP55 with insulation to class F. Motor shall have integral thermal overload protection, sealed for life bearings and designed to run at any angle. Fan/Motor assembly shall be able to be withdrawn from its casing and turned through 150° to change air flow direction even after duct connection.

309.4.3.3 Accessories

Unit to be complete with two mounting pads, four adjustable feet, foot fixings, two quickfit matching flanges and single bolt self sealing clamping collars, two flexible connectors, matching electronic speed controller, pair of wall mounting brackets, inlet cone and wire guard, antibackdraught damper, converter from quickfit to bolted flanges.

309.4.4 Kitchen Fume Fans

309.4.4.1 General

Kitchen fume fans shall be either axial or centrifugal duct mounted type suitable for extracting fumes and steam, efficient, and designed for low sound level. Fan shall be complete with flexible duct connectors, backdraught and lower shutters, external grille, electrical speed controller, worm drive clips, vibration isolators.

309.4.4.2 Hood

Kitchen hood shall be of Aluminum with V type grease trap washable filter of 50 mm thick designed for maximum face velocity of 1m/s complete with oil drainage facility and shall be to the engineer approval.

309.4.5 Window / Wall Fans

309.4.5.1 General

Window / wall fans shall be of the axial type that can be installed on window or wall, easy to install, esthetic and very silent, made of injected moulded plastic and rated class II electrical insulation.

309.4.5.2 Motors

Single phase motor, shaded pole type, suitable for 220-240 V, 50HZ, low consumptions fitted with internal thermal protection.

309.4.5.3 Accessories

Speed controller operable throug cord and remote fan switch, back draught shutters, wall fixing Kit, extended duct, and wall grille.

309.4.6 Special Application Axial Flow Fans

309.4.6.1 General

Ventilation fans used in water treatment plant such as in dewatering, chlorination, RAS and primary sludge pumping stations shall be belt driven axial fans suitable for flanged duct mounting for industrial application and extraction of high temperature gas up to 150° C, and corrosive and explosive gases.

Casing shall be made of rolled and electro-welled steel plate. The motor support shall be fitted outside the casing and the impeller support is welded inside. A steel sheet case protects the belt and the bearings. The whole assembly is furnished with gray epoxy paint. The casing is fitted with a spigot port.

309.4.6.2 Impellers / motors

Impellers shall be made in die-cast aluminum in one piece, with airfoil profile fixed blades, dynamically balanced according to ISO 1940 and finished with red epoxy paint. Impeller shall be driven by vee-belt drive. Motors shall be induction asynchronous according to IEC 34-1, 4 poles IP55, class F insulation, ball bearings greased for life, and cooling fan mounted externally on the fan.

309.4.6.3 Accessories

All duct work shall be flanged type complete with gasket sealant, flages, nuts, bolts, and washers, made of corrosive resistant steel coated with gray paint.

309.4.7 Roof Cabinet Twin Fans

309.4.7.1 General

Rectangular unit housing to be manufactured in aluminum allory and to contain a removable fan assembly comprising a directe driven centrifugal fans. Exhaust to discharge vertically through high velocity outlets protected by hinged birdguards, which automatically open under pressure. Units shall be fitted with two fans / motors: one runs, the other standby. Units to be provided with internal isolator and control prewired box. Motorst and fans shall be easily acceassable by removing the top cover sewred into the frame with bolts. Waterproof Frame finished in polyester powder paint.

309.4.7.2 Fan / motor

Fan blades shall be manufactured in aluminium alloy with asymetrical blade spacing, to be dynamically balanced. Motors, manufactured to BS 5000, TEFC, IP55, class F insulation incoorporating greased for life bearings, two speed motor.
Resilent mounting shall be supplied to support the fan and motor assembly on the baseplate to minimise machanical noise and vibration.

309.4.7.3 Accessories

Unit shall be supplied with flanged duct flexible connections on the suction side. Antivibration pads for external mounting of the unit on the concrete base.

Twin Fans Microsave control system utilising extra low voltage interface system. Controller to comprise a control module fitted to the twin fan unit which shall interface with the interface control panel (CP) via (24V) 4 core screened signal cable (0.55 mm^2) PVC coated (240V outer insulation). The ICP shall have a touch sensitive switch to select the fan mode and shall incoorporate coloured L.E.D.'s to in dicate fan and control status and is to include an "OFF" position. The I.C.P. shall be the same size as a surface mounted double gang power socket and the facia plate incoorporating electronics suitable for recessing into a plastic double gang power outlet. I.C.P. shall be manufactured in Fire retardant ABS plastic (VO rated) and installed as shown on drawing (REAF-S).

309.4.8 Roof Axial Cowl Fans

309.4.8.1 General

Fans shall be suitable for roof mounting on purposed made upstand as shown on general standard drawings designed to extract air with a horizontal discharge and with the motor shaft in the vertical position. Housing shall be made in polyester with fiberglass.

309.4.8.2 Impellers / Motors

Impellers made of injection moulded plastic reinforced with chemically anchored fiberglass and or cast aluminium protected with epoxy paints, and dynamically balanced in accordance with ISO 1940.

Motor shall be 4 pole, 2 speed asynchronous squirel cage in die cast aluminium in accordances with IEC 34-1: 220-240 V/ 50HZ single or three phase, class F, IP55 complete with thermal overload protection incoorporated in the winding with connections to the terminal base and greased for life ball bearings.

309.4.8.3 Accessories

Motors shall be provided with backdraught shutters preventing air entry when the fans are switched off.

Remote fan switch room mounted as shown on drawings (FEAF-S).

309.4.9 Centrifugal type power roof ventilators

Fans shall be V-belt driven with backward inclined, non-overloading wheel. Motor compartment housing shall be hinged or removable and weatherproof, constructed of heavy gauge aluminum. Fans shall be provided with birdscreen, disconnect switch, backfraft dampers and roof curb. Motors enclosure shall be explosion-proof type. Lubricated bearings shall be provided. All interior fan components shall be coated with a minimum 5-mil thick of Air Dray Phenol.

309.4.10 Air Filters

Air filters shall be listed according to requirements of UL 900, except high efficiency particulate air filters of 99.97 percent efficiency by the DOP test method shall be as listed under the Label Service and shall meet the requirements of UL 586.

309.4.11 Factory painting

Units which are not of galvanized construction according to ASTM A 123 OR ASTM A 525 shall be factory painted with a corrosion resisting paint finish. Internal and external ferrous metal surfaces shall be cleaned, phosphatised and coated with a paint finish which has been tested according to ASTM B 117, ASTM D 1654 and ASTM D 3359. Evidence of satisfactory paint performance for a minimum of 125 hours for units to be installed indoors and 500 hours for units to be installed outdoors shall be submitted. Rating of failure at the scribe mark shall be not less than 6, average creepage not greater than 1/8 inch. Rating of the inscribed area shall not be less than 10, no failure. On units constructed of galvanized steel which have been welded, exterior surfaces of welds or welds that have burned through from the interior shall receive a final shop docket of zinc-rich protective paint according to MS MIL-P-21035.

309.5 AIR DISTRIBUTION DUCT SYSTEM & DAMPERS

309.5.1 Duct works

All sheet metal ductwork shown on the drawings, specified required for various ventilation systems shall be fabricated and furnished from best quality cold rolled, close annealed, plain finished not salted, galvanised mild steel sheets of soft bending quality specially suitable for air conditioning works. Ducts shall be fabricated, assembled and connected in accordance with following table (applicable to galvanised ducts).

Dimension of Largest side mm	Sheet thickness mm	Transfer Reinforcing Between Joints	At Joints
Up to 400 mm	0.6	Not required	Drive slip
600	0.8	Not required	Pocket lock at 90 cm
800	0.8	Not required	Pocket lock at 90 cm
1000	0.8	40 mm x 40 mm x 4 mm at 90 cm	Pocket lock at 90 cm
1250	1.0	40 mm x 40 mm x 4 mm at 90 cm	Pocket lock at 90 cm
1600	1.0	40 mm x 40 mm x 4 mm at 90 cm	Pocket lock at 90 cm

Note: Sheet metal thicknesses are net minimum acceptable after accounting for manufacturing tolerances and should be as measured on site by a micrometer. Otherwise the next higher thickness indicated shall be provided in order to meet the specified thickness. Exhaust air duct from kitchen shall be manufactured from aluminium sheet with thcikness two gauges heavier than galvanised duct.

All bracing and reinforcement angles shall be made of black steel, properly cleaned from rust and painted with 2 prime coats of antirust red paint prior to installation. Angles shall be carried around all four sides of ducts.

Guiding vanes and deflectors shall be installed as shown on the drawings and where required for good air flow. Unavoidable pipe crossing with ducts, conduits, or structural members, shall be approved by the Engineer before erection.

The penetration shall be through a streamlined tight galvanized sheet sleeve of aerodynamic shape without reducing the cross section area.

All bends shall have a radius equal to 1.5 times the width of the duct. Otherwise, bends shall be right angled with streamlined double deflecting vanes.

Good workmanship air tightness and system cleanliness shall be foremost considerations. The interior of all ducting systems shall be clean before erection and all open ends, which are left as the work progresses, shall be temporarily sealed to prevent the ingress of dirt. Mastic type sealing compound shall be used to make duct joints airtight.

All ducting systems shall be adequately supported and all fittings shall be manufactured and installed in accordance with good practice to minimize air turbulence, noise generation and friction loss. Particular attention shall be paid to the selection and location of an adequate number of dampers of suitable type for flow regulation. Consultation with the system designer is recommended to ensure that the regulating procedures to be carried out at commissioning stage may be achieved.

Sufficient thermometers, test points and access doors shall be provided for commissioning and for operating and maintenance purposes.

Provision shall be made for the possibility of dismantling ducting connections and equipment for servicing/removal and suitable precaution shall be taken to prevent transmission of vibration.

Ductwork shall be adequately braced and stiffened to prevent ‘drumming’. Where insulation incorporates a vapour seal, special care shall be taken to ensure the continuity of that seal and to prevent any damage before hand-over.

All dampers shall be checked to ensure that they are properly installed and that the blades and linkages move freely. Where tight shut-off is required checks shall be carried out to ensure there is no undesirable leakage around damper frames or through the assembly in the closed position.

309.5.2 Volume control dampers (VCD)

Manual volume control dampers shall be provided as shown on the drawings or as required additionally for balancing purposes. The dampers shall have sturdy corrosion resistant construction.

Damper quadrants shall be cast metal type with words ‘OPEN’ and ‘SHUT’ clearly marked in raised letters. All dampers shall have multi-leaf, double skin aerofoil section opposed action blades. Individual blades should not exceed 1200 mm in length or 175 mm in width. Double skin blades shall be made out of minimum 22 gage galvanised steel sheet. Damper frames shall be made out of 16 gage galvanised steel sheet.

Single blade dampers with single skin blade section may be used for damper size upto 300 x 300 mm. Single skin blades shall be fabricated from 18 gage galvanised steel sheet.

The blades shall be securely bolted/riveted to plated steel spindles, the ends of which shall be extended to the outside of the damper frame, each with a groove in line with the blade. Spindles shall be carried in brass or nylon bearings. The control linkage shall be outside the air stream. Shut-off dampers shall incorporate rubber blade edges to minimise leakage past the dampers.

Final position of the quadrant handles after balancing the air system shall be clearly marked.

The location of all concealed fire dampers and volume control dampers shall be indicated.

309.5.3 Fire dampers (FD)

Fire dampers shall be of curtain blades outside airstream dampers are designed to stop the spread of fire through ducts, walls and floors and shall be supplied to exact requirements.

The damper blades shall be precision roll-formed and then interlocked to provide a ‘curtain’ with an angular, heat deflecting construction. All dampers shall be supplied with two constant force stainless steel closure springs and locking ramps to ensure positive closure. Dampers shall be supplied as standard, with an easy maintenance fusible link for ease of testing and resetting dampers. The link is set to operate at 72°C unless otherwise stated.

The fire dampers shall be manufactured as standard from corrosion resistant galvanised mild stee. Should offers superior fire performance characteristics.

The fire dampers shall be designed in accordance with BS476 Part 8 (2 hour rating) and tested and approved.

Units of this type are factory assembled ready for site installation. They shall be supplied complete with installation frames.

309.5.4 Grilles and diffusers (SCD/RCD/ECD/SWG/RWG/EAG)

Grilles and diffusers shall be of rugged construction and made of anodized aluminium with removable cores, turning vanes and volume control dampers for final fine control.

Prior to installation, their location shall be approved by the Engineer and shown on shop drawings.

They shall meet the following requirements:

- noise level shall not exceed 40 dBA when measured at a distance of 1 meter from the grille
- air velocity in the occupied zone shall not exceed 0.25 m/s.

Grilles and diffusers shall be installed by concealed hooks. Junctions between ducts shall be as shown on the drawings.

Wall mounted grilles shall be fitted with a wooden frame to be secured before rendering works.

Grilles shall have manually adjustable sheet steel fins, 1 mm thick, easily accessible from the exterior.

309.5.5 External air louver (EAL)

Extract and fresh air external louvers shall include:

- A frame made of angle iron to be fixed to the wall
- A frame with rainproof fixed fins and bird screen grille.

Louvers shall meet the following requirements:

- Velocity of air : 500 FPM maximum
- Head loss : 5 mm water column maximum

309.5.6 Bird screens and frames

Bird screens shall be installed on all fresh air inlet louvers and shall conform to FS RR-W-360, Type I, Class 1, 2 by 2 mesh, 0.063 inch diameter aluminum wire or 0.031 inch diameter stainless steel wire. Frames shall be removable type or stainless steel or extruded aluminum.

309.5.7 Air filters

Filters shall be provided for fresh air and for mixed fresh and return air.

For both the applications, the filters shall be 50 mm thick permanent metallic washable type. Filter media thickness shall be not less than 45 mm. (Synthetic or natural washable filter media may be used with prior approval. Self cleaning inertia type fresh air filters may be necessary for large installations.

Filters are normally placed upstream of the main supply fan and the cooling coil. Apart from producing clean room air, this protects cooling coils and other apparatus from deposition of dust. The system shall be arranged to provide an even velocity distribution across the filter face.

Where extra clean contamination free air is required, high efficiency filters, normally used in conjunction with prefilters, are placed down stream of the fan and shall be the last item of equipment before the discharge point. This ensures that any air leakage is outward and that contaminated air is not drawn into the system, also that any contamination from air handling equipment (e.g. carry-over of dust particles from humidifiers) is captured by the final fiter. Prefilter construction shall be as described above.

309.5.8 Fresh air intakes (FAI)

Fresh air intakes shall be as remote as possible from concentration of surface or roof dirt and positioned to avoid intake of fumes or odours. Inlet grille or wire mesh bird/insect screen and volume control damper shall be fitted ahead of fresh air filters. In some cases the fresh air intake may need acoustic treatment to reduce noise from or into the system. Air inlets shall be positioned at least 1.2 m above ground level. Goose neck connections shall be provided to prevent ingress of rain water. sand traps may be required in areas which experience high incidence of dust.

Adequate access to facilitate servicing of the filters shall be provided and access doors, ladders, electric lighting included where necessary.

All ducts shall be clean and free from builder’s rubble and dust before filters are installed. The correct flow direction shall be observed. The frame holding the filter media, when in position, shall form an effective seal so that no air bypasses the filter.

309.6 THERMAL INSULATION

309.6.1 General

Insulation shall be carried out neatly and to high standard by skilled workers, experienced in the trade.

The thermal insulation shall be non-corrosive to the metal, water repellant and fire retardant.

All metal surfaces shall be thoroughly cleaned and treated with approved corrosion inhibitor before applying insulation. Inhibitor coating would not be required for galvanized surfaces.

All duct flanges, stiffeners and inspection doors etc. should be insulated in accordance with the recommended practices and to the Engineer’s approval. Strainers, valves (size 80 mm and above) and other fittings which require opening for maintenance/repairs shall be provided with insulated boxes. Inspection door insulation thickness shall match the surrounding ducts.

All openings in roof slabs and walls for passing ducts and pipes should be suitably weather proofed. Metal sleeves should be provided where ducts or pipes pass through masonry walls or partitions. All openings in roof, ceiling or walls made for the purpose of ACHVR installation shall be sealed to prevent ingress of rodents, insects, dust, moisture and water. Openings in equipment casings shall be sealed likewise.

All duct and pipe insulation shall be covered with cotton canvas/fiberglass cloth and vapour sealed. The cloth shall be soaked in approved weather proofing compound and wrapped carefully to provide a smooth surface, free from wrinkles and gaps. There should be at least 50 mm overlap at transverse and longitudinal cloth joints. Second coat of vapour seal shall be applied after drying of the first coat. This vapour barrier finish shall be carried over the load bearing inserts at location of supports or hangers without discontinuity or punctures.

The vapour seal material shall be fire resistant, non-toxic, weather resistant and anti-fungus quality. Bitumen based products shall not be used.

309.6.2 Rectangular ductwork insulation

All rectangular supply and return duct work shall be insulated with rigid fiberglass slab covered with reinforced aluminium foil. The slabs shall be free from shot or coarse and have density of not less than 48 kg/m^3 and thermal conductivity not more than .037 w/m °C. The slabs shall be fixed applying approved adhesive material of high quality to entire surface of both the duct-work and insulation slabs and fixed in place immediately. (The adhesive shall be applied to both the edges of the slab also). All joints shall be sealed using 75 mm wide self adhesive tape. Minimum time should be permitted to lapse between applying self adhesive tape and applying vapour barrier to insulated surfaces.

All duct work external to the building shall be insulated with 50 mm thick fiberglass slab and covered with fiberglass cloth of 200 gm/sq.m quality.

All duct work within the building, except plant rooms, shall be insulated with 25 mm thick fiberglass slab and covered with high quality canvas of 200 gm/sq.m quality.

Fresh air and exhaust air ducts shall be suitably insulated wherever possibility of external or internal condensation exists.

Hardwood battens shall be provided between the ducts and the supports. Wood shall be treated for protection from fungus and termite.

Plastic insulation hangers shall be provided as additional support to the insulation of rectangular ducts with a side dimension in excess of 600 mm. Hangers shall be fixed to the bottom and sides of the ducts using blind rivets spaced 300-400 mm apart.

309.6.3 Circular ductwork insulation

Circular supply and return air ductwork shall be insulated with flexible fiberglass blanked of density 24 Kg/m^3 covered with reinforced aluminium foil. Blanket thickness shall be 50 mm compressed to 25 mm during application for internal ducts and 100 mm compressed to 50 mm for external ducts. Method of application of insulation shall be same as for rectangular ducts. In addition, 25 mm wide aluminium bands shall be provided at 500 mm centers.

Sectional treated hardwood rings or approved plastic inserts shall be provided between the ducts and the supports.

Vapour sealing over the insulation shall be carried out in the same manner as for the rectangular ducts. Additional protection shall be provided for exposed insulated circular ducts, if specified.

Preinsulated flexible ducts shall be subject to the approval of MEW. Insulation density shall be not less than 16 Kg/m^3. Insulated flexible duct connections to grille/diffuser plenums shall be covered with canvas and vapour sealed as per the rest of the air ducts.

309.6.4 Drain pipe insulation

All condensate drain pipes within plant room or other internal areas subject to damage or sweating shall be insulated using 25 mm thick glassfibre or 10 mm foam rubber insulation applied and vapour sealed as for duct insulation.

309.6.5 Refrigerant pipe insulation

Refrigerant suction lines shall be insulated using 19 mm thick foam rubber or 50 mm thick rigid fiberglass and vapour sealed in the same manner as duct insulation. Refrigerant suction lines of small split air conditioners (upto 2.5 Ton nominal capacity) may be insulated using 10 mm foam rubber and vapour sealed. Refrigerant suction lines within packaged equipment shall be insulated with at least 19 mm rubber foam with protective paint. Metal cladding over insulation may be specified for large evaporator shells.

309.7 SOUND AND VIBRATION CONTROL EQUIPMENT

309.7.1 General

Care shall be taken in the selection and location of mechanical and electrical equipment to ensure that the noise or vibration that it produces does not cause annoyance to occupants within the building where it is located or to people in surrounding areas (either indoors or outdoors). Particularly careful consideration shall be given to the sitting of outdoor equipment, including cooling towers, if required, air cooled condensers, remote condensing units, externally mounted fans. Specialist advice is essential when large machines are to be mounted on roof or intermediate floors.

Proper consideration shall be given to the sitting of supply and exhaust louvers on the building exterior to prevent problems owing to unwanted sound passing outward (or inwards) through these openings.

309.7.2 Sound attenuators

Sound attenuators and lining materials in duct work systems, and anti-vibration devices for equipment, shall be located strictly in accordance with design requirements and manufacturer’s recommendations.

Installation of specially designed sound attenuators shall be preferred over duct lining.

The material employed for sound absorption within attenuators, mixing boxes and room terminals and ductwork lining are generally susceptible to physical damage and to severe deterioration if exposed to rain or water. It is essential that adequate protection is provided not only during storage and installation, but at all times upto system handover.

309.7.3 Antivibration devices

Anti-vibration devices include compression materials and rubber in sheer isolators. These materials may be damaged physically, or by liquid such as oil, and adequate precautions are therefore essential.

Packaged units, installed at ground level, indoor free standing units and air handling units shall be mounted on anti-vibration units in the form of multilayer rubber pads. Equipments installed on the roof may be mounted on rubber pads or springs suitably selected and approved by the manufacturer.

Multi layer pads shall be composed of rubber sheets, preferably with square grid pattern on both sides, and steel sheet inserts of 16 gauge. The composite pad thickness shall be selected to suit the equipment, but shall be not less than 32 mm.

AV pads for small packaged units, air handling units, condensing units, fans, etc. shall contain counterbored holes and fitted with suitable rubber grommets to permit free passage of foundation bolts without making contact with the equipment.

Spring type vibration isolators shall be fitted with limit stop to prevent excessive movement and there shall be a compensating pre-setting.

Care shall be taken to prevent any anti-vibration devices being loaded beyond their safe limits during erection of machinery.

309.7.4 Flexible duct

Flexible duct joints shall be provided at inlet and outlet of each fan, air handling unit and packaged unit. The joint material shall be flame retardant.

309.7.5 Others

Flexible electrical conduits shall be provided for final connection to chillers, pumps, air handling units, fans and any other vibrating equipment.

Care shall be exercised to ensure that antivibration mounts are not “bridged-out” by direct contact between the equipment and building structure through foundation bolts, hangers, rigid pipe or cable connections, rigid clamping of equipment body to any element of the building or through bottomed mounting springs. <u>All shipping bolts and stoppers must be removed before commissioning.</u>

309.8 INSTRUMENTATIONS

309.8.1 Test points for air distribution system

Adequate test hole fittings shall be provided in the air ducts to facilitate accurate measurement of air flow using pilot tube traverses. Test hole fitting shall have at least 25 mm dia bore complete with an effective removable seal. Location of test points should be clearly marked on the insulation surface.

Test points shall be provided at the following locations :
- At all fans 9in the straightest section of duct near to the outlet).
- At main branches.
- After regulating dampers.
- After cooling coil and heating batteries.
- At any other position indicated on the drawings or necessary for balancing the air system.

309.8.2 Manometers

U-tube type manometers shall be installed to measure the pressure drop across filters. The manometer shall have coloured fluid for easy readability and the tube shall be protected by a metal or plastic casing.

Manometer shall be installed at the following locations :

- Across fresh air filters of large air handling units.
- Across fresh air filters of air handling units for 100% fresh air applications.
- Across mixed fresh and return air filters of air handling units and packaged units for normal air conditioning.
- Across all high efficiency filters.

Inclined tube manometers may be used for special applications.

309.8.3 Smoke detectors

A smoke detectors suitable for duct mounting shall be installed in the main returns air duct adjacent to each packaged unit. The smoke-detector shall be photoelectric obscuration type and shall be interlocked with the motor to stop it in the event of smoke detection. It should operate on 240 volts with two volt free contacts and shall be manual reset type.

309.9 CLEANING AND ADJUSTING

Equipment shall be wiped clean, with traces of oil, dust, dirt, or paint spots removed. Temporary filters shall be provided prior to startup of all fans that are operated during construction, and new filters shall be installed after all construction dirt has been removed from the building. System shall be maintained in this clean condition until final acceptance. Bearings shall be properly shall be properly lubricated with oil or grease as recommended by the manufacturer.
Belts shall be tightened to proper tension. Fans shall be adjusted to the speed indicated by the manufacturer to meet specified conditions.

310. GAS CHLORINATION

310.1 GENERAL

Gas chlorination equipment for installation at pumping stations, reservoirs and water treatment works and other locations on the system generally come under one of two categories.

a) Gas chlorination feeding into pressurised and gravity lines at locations where an electricity supply is available.

b) Gas chlorination at those locations, such as water catchment works, outlets from reservoirs etc where there is no electricity supply.

This specification cover both categories.

The Contractor is responsible for the safe design, provision and installation of the chlorination dosing system and associated safety equipment. The safety equipment required varies from site to site depending on site location, quantity of chlorine stored or dosed and type of equipment supplied. The contractor shall access the requirements of each installation with respects to the following points:

- ventilation system
- leakage detectors
- audio and/or visual alarms
- automatic shut down systems
- personal protection equipment
- procedures and training.

The equipment called for in this section are nominal requirements, and shall be supplemented with required system per manufactures recommendation for safety and operation.

310.2 SCOPE OF WORKS

The scope of works for the provision of chlorination equipment includes, as appropriate to the particular category above:

1. Supply and transport to site of all equipment including chlorinators, centrifugal booster pumps, chlorine bottles, and all other material and equipment necessary for the installation.
2. Installation of chlorination equipment and fittings, pumping equipment, metering, pipework and valves, control and protection equipment to form an effective and fully operational installation.
3. All necessary civil and building works.
4. Testing commissioning and putting into service all equipment.

310.3 VACUUM CHLORINATION OF PRESSURISED WATER SYSTEM

This system is applicable at pumping stations, water catchment works etc where the water to be treated is under pressure and electricity is available.

A centrifugal booster pump shall be provided to supply pressurised water to the chlorinators.

Where specified the rate of chlorine injection shall be controlled by flow metering and valving as a function of the water flow rate.

Equipment Characteristics

Injection of chlorinated solution shall be by vacuum type chlorinator, the vacuum being achieved by pressurised water and injector.

The chlorinator may be either wall mounted or mounted directly on the head of the chlorine bottle. It shall include:

- Pressure reducing valve
- Flow control valve
- Injection device
- Pressure relief valve to act in case of surge pressure of chlorine or loss of suction.
- Pressure gauges up and downstream of the booster pump.
- Non return valve downstream of the chlorinator.

The injection service pressure (bar) and chlorinator capacity shall be calculated by the Contractor and designed from information in the particular specification for each installation.

The Contractor shall supply all necessary equipment and fittings for operation, control and maintenance in accordance with the following list.

The list is indicative and by no means restrictive.

Water Circuit

a) Motor Driven Pumpset
An electric motor driven pumpset shall be provided to achieve the discharge rate and pressure for chlorinator operation.
The booster pump discharge rate and pressure shall be as the chlorination equipment manufacturers specification. The pump assembly shall comprise a three phase 380V electric motor with a minimum protection class IP55 and maximum speed of 3000 rpm., and a centrifugal pump mounted on a common base plate.

b) Non return valve downstream of the pump.

c) PVC or bronze valves (Upstream and downstream of the pump)

d) PVC or bronze control valve downstream of the pump.

e) Bronze strainer (1mm) upstream and downstream of the pump.

f) 10 or 25 bar pressure gauges as appropriate upstream and downstream of the pump.

g) Piping, treated against or resistant to corrosion.

Chlorine Circuits

a) Chlorine resistant non-return valve.

b) Anti-siphon system

c) Chlorine resistant chlorinated solution injection device.

d) Chlorine resistant pipework for chlorinated solution injection.

e) Chlorine resistant pressure relief piping for release of gaseous chlorine in the event of over pressure, to a maximum length of 8m.

f) Piping between chlorinator and injection device, complete with fittings, all of chlorine resistant material.

310.4 CHLORINATION OF PRESSURISED AND GRAVITY SYSTEMS IN THE ABSENCE OF ELECTRIC POWER SUPPLY

This system is for use where there is no power supply available, for example supply and delivery lines at reservoirs, catchment areas and headworks.

The chlorination process shall cease immediately in the event of lack of water.

a) Chlorination under low pressure

Use of low pressure chlorinators shall only be used where use of vacuum types is impossible due to insufficient line pressure.

The chlorinator shall be either wall mounted or directly assembled to a gaseous chlorine bottle, the latter providing pressure for operation of the chlorinator. A chlorine resistant piping connection shall link the chlorinator to a diffuser. In the case of a reservoir a spring loaded check valve shall be installed at the point of chlorine injection.

A nozzle injector rather than a diffuser shall be used for injection into a pipeline.

Where injection is into the pipeline pressure in the line shall always be more than 0.1 bar (g) and shall not exceed 0.7 bar (g). Partial vacuum in the pipe must be prevented.

In the case of a reservoir the level of water in the reservoir shall always be at least 1m above the diffuser.

The size of the piping between the chlorinator and the injection point will be a function of both dose rate and distance between the points.

b) Chlorination by Vacuum Chlorinator

Chlorination under vacuum only applies to reservoir gravity supply lines, the latter associated with a minimum hydraulic pressure of 0.5 bar. A hydro ejector shall achieve the required hydraulic pressure for injection provided a pressure drop is produced downstream of the hydro ejector feed point (By a valve or diaphragm).

The Contractor shall optimise the locations of feed and injection points in such a way as to achieve a minimum hydraulic pressure of 0.5 bar upstream of the hydro ejector. The capacity of the chlorinator shall not exceed 200 gr/hr at a hydraulic pressure of 0.5 bar or 300 gr/hr at a pressure of 1 bar, unless otherwise specified.

Chlorination shall cease immediately in the event of lack of water in the line.

c) Chlorination Dosing Pump

Disinfection shall be achieved by injection of chlorinated lime or sodium chloride (Javel water), by means of a dosing pump proportionally to the rate of flow of water. The chlorinated solution shall be stored in corrosion proof tanks.

The operation of the dosing pump shall be controlled by a flow meter equipped with a pulse transmitter. A control system receiving the transmitted pulses, shall regulate the dosage of chlorinated solution.

Supply of power shall be by:

A low leakage, self discharge, maintenance free battery with no water addition required.

A battery charging solar panel complete with either a charge regulator or an electronically controlled battery charger housed in a class IP55 box equipped with LED indicator. The contractor shall supply and install such other equipment as may be necessary for the operation of the system.

310.5 CONTROL SYSTEMS BASED ON FLOW RATE OF WATER

310.5.1 General

The control system shall comprise a chlorine injection regulating system. It shall include:

a) A chlorinator for use with pressurised water systems.

b) A water flow meter with an output signal proportional to the rate of flow to be treated.

c) A motorised chlorine flow control valve with feedback signal to the control system, the signal to be proportioned to the chlorine injection rate.

d) A feed back control system with signal comparator. In the case of signal discrepancy the control valve servomotor shall be actuated to adjust the injected dose of chlorine.

e) The injection nozzle and/or hydro ejector.

f) If specified the facility to receive a signal from a residual chlorine analyser which will adjust the chlorine/water ratio.

310.5.2 Requirements of the above Control Systems

a) Chlorine Flow Control Valve

The motorised control valve shall be functionally compatible with the chlorinator. It shall achieve automatic control of the chlorination process as a function of the rate of flow of water to be treated.

The supply voltage shall be 220V, 50 Hz with a two pole circuit breaker equipped with adjustable thermal trip.

The valve capacity shall not exceed 10 kgf (gaseous chlorine)/hr. It shall receive and transmit a 4-20 mA signal to the chlorinator. The valve can either be incorporated in the chlorinator or installed separately in the system.

b) Water Meter

The water flow meter which may be of the turbine, magnetic flow, diaphragm or ultrasonic type, shall control the operation of the motorised control valve. It shall have the following characteristics.

a) Be suitable for fluids with up to 80 mg/l solids particle content. It shall be designed for a range of water velocities from 0.5 to 3.0 m/s and shall transmit a 4-20 mA signal.
b) Operate on a supply voltage of 220V or 110V - 50 Hz.
c) Be equipped with a rate of flow indicator.

310.6 CONTROL SYSTEMS BASED ON RESIDUAL CHLORINE METERING

310.6.1 General

The system shall include:

a) A vacuum chlorinator injecting into a pressurised water system.
b) Chlorine injector flow control valve actuated by a converter to a residual chlorine analyser with signal transmission to the control valve of a signal proportional to residual chlorine concentration in the treated water.
   The residual chlorine analyser shall be equipped with an electronic transmitter, and shall be one of two types.

310.6.2 Type “A” (with reagent)

The residual chlorine analyser shall be of the amperometric type for measurement of residual chlorine in water.

It shall include:

1. Measuring cell.

2. Suitable reagent to allow measurement of the concentration of total and/or free residual chlorine.
3. Amplifying circuit and converter with 4-20 mA output signal. The above to be incorporated in the analyser bar.
4. Zero point and scale adjustment features with automatic temperature compensation feature, to compensate for errors due to temperature fluctuation of the sample.
5. Direct reading indicator.
6. All components to be installed in a corrosion resistant box. The characteristics shall include:

   - Scale range 0-0.5, 0-2.0 mg/l
   - Water sample temperature range 0-50ºC.
   - Output signal 4-20 mA
   - Supply voltage 220v - 50 Hz with 2 pole circuit breaker with adjustable thermal trip.
   - Indicator: located on front of analyser.
     Direct reading in mg/l
     Accuracy ±2% of scale range.

310.6.3 Type “B” (Dry Type)

The analyser shall consist of a potentiometric cell fitted with three metallic electrodes that shall generate a current directly proportional to the concentration of free residual chlorine.

It shall be equipped with a potentiometric amplifier and a converter to transform the current to a 4-20 mA signal.

The circuitry shall include a zero point and scale adjustment feature as well as automatic temperature compensation feature (Thermistor) in order to compensate for errors due to temperature fluctuations of the sample.

It shall have a direct reading indicator and be installed in a corrosion resistant box.

- The characteristics shall include:
- Scale ranges 0-0.5, 0-2 mg/l
- Water sample temperature range 0-50ºC
- Output signal 4-20 mA
- Supply voltage: 220V - 50 Hz with 2 pole thermal magnetic circuit breaker.
- Indicator: located on front of analyser
  Direct reading in mg/l
  Accuracy ±2% of scale range.

310.7 AUXILIARY EQUIPMENT FOR CHLORINATION AND STORAGE

310.7.1 General

Where electric power is available the chlorination room shall be equipped with an extractor fan roof mounted cowl typetop discharge (10m static pressure), suitable for chlore extraction. The fan shall be connected to a PVC pipe of 100mm bracketed off the internal wall of the rroms. The pipe shall run vertically inside the rooms and be fitted with a mosquito net and weather cowl at the inlet. The fan shall give twenty air changes per hour and shall have a control switch located outside the building. A sign shall be fixed outside on the door “Danger, Toxic Gas - Access for authorised personnel only”.

These shall be available at each chlorination building 2 No gas masks consisting of an integral mouth piece and wide view visual piece covering the entire face, complete with flexible breathing tube and filter cartridge with hipstraps.

2 No additional filter cartridges shall be supplied with each mask. The masks shall be kept in a dedicated wall mounted cupboard in the control room or attendants room. The cupboard door shall have affixed to it a label stating “Chlorine gas masks. Fit new cartridge before use "قناع واقٍ من غاز الكلور - بدل القارورة قبل الاستعمال" , in both Arabic and English.

The filter shall be effective in neutralising gaseous chlorine.

A emergency eye wash and shower system shall be fitted to the wall immediately outside the chlorination room for emergency use. It shall have a chain operated valve.

When specifically called or deemed necessary, the chlorination room shall be fitted with an orange windsock of airport quality mounted on the top of the building. The sock shall be made of nylon and shall be chemically treated and ultraviolet dyed to prevent fading. The sock shall be mounted on a frame specially made for this application that does not lock up and shall be visible from the entrance door of the chlorine building.

310.7.2 Chlorine Bottles

2 No chlorine bottles shall be supplied with each chlorinator. They shall be 50 kgf capacity each unless specified otherwise.

Each bottle shall be equipped with:

- An isolating valve, which shall be provided with a protective cap during transport.
- Where specifically called for, an automatic chlorine supply change over to a standby bottle on depletion of the duty bottle. The system shall be wall mounted and shall be functionally compatible with the chlorinators. It shall function on partial vacuum and shall be complete with all accessories and fittings The change over switch should include an indicator showing the cylinder in service.
- A bottle rack and chain support.
- Where specifically called for, a permanent weighing device shall be provided beneath the bottle in service to continuously monitor the rate of chlorine consumption.

310.7.3 Chlorine Detector

Where specifically called for or deemed necessary, gaseous chlorine detector units shall be fitted. The gas leak detector shall be used in conjunction with an alarm which shall be actuated if the gas concentration arises above 1 ppm or 3 mg gas/cu.m of air.

The detector may be one of two types:

310.7.3.1 Type A (Dry Cell)

The gas detector shall consist of an independent tank and detection cell located outside the tank. The tank capacity shall be sufficient to give 6 months operation. The detection cell (sensibility 1mg/cu.m) shall be connected to an electronic measuring device located in a wall mounted box. In the presence of an oxidising gas the detection cell shall generate a current proportional to the gas concentration.

The box shall have an electronic indicating device and shall give continuous monitoring.

When gas concentration reaches its maximum permissible limit the detector shall activate visual and acoustic alarms, and shall trigger the operation of a remote alarm, where fitted, the operation of the extractor fan and closure of the supply line valves.

A test push button shall be provided to allow the operation to be checked.

310.7.3.2 Type B (Wet Cell)

The detector shall have live electrodes under constant supply voltage, immersed in an electrolyte that shall conduct current in the presence of an oxidising gas. The generated current shall be amplified and converted to a signal.

310.8 LEAK DETECTION, RESIDUAL, FREE RESIDUAL AND TOTAL RESIDUAL MEASUREMENT

A bottle of liquid ammonia for chlorine vapour leak detection purposes and a measuring kit for quick determination of the concentration of the following shall be provided with every chlorination equipment installation.

- Free residual chlorine
- Residual chlorine
- Total residual chlorine

Details of the equipment to be provided, which shall include all auxiliaries, shall be provided with the tender.

310.9 MONITORING AND CONTROL

The chlorination system shall have interface signals for the monitoring and/or control by a central computer station as specified.

As a minimum requirement, the chlorination system shall acquire the flow measurement analogue signal and provide the following outputs:

- RS 485 interface output for data exchange with computer based systems (PLCs, Monitoring station, etc.)
- Residual chlorine analogue signal where specified.
- Booster pumps status (ON/OFF/FAULT).
- Chlorine leak detection alarm.

- Vacuum switch alarm. This switch shall be integrated or fitted to the chlorometer to signal high or low vacuum level to the plant control system. The alarm shall be visual and audible. The switch contacts shall be set at manufacture as required by the particular site at which the chlorinator is to be installed.

310.10 INSTALLATION OF EQUIPMENT

The location of the chlorine bottles in the store shall be away from direct sunlight at all times. During transportation of bottles the contractor shall ensure that gas bottles are not overturned and that safe handling procedures are adopted at all times.

Gaseous chlorine piping connections between system components shall follow the shortest and most direct route possible and shall be laid to falls.

Water and other piping shall not be laid immediately alongside gaseous chlorine piping in order to prevent cooling and condensation.

Only grease or other lubricant as recommended by the equipment manufacturer shall be applied to all removable fittings.

Where the chlorinator is installed remote from the gas bottle the distance apart shall not exceed 10 metres.

The chlorinator vapour vent pipe shall be extended to outside the building away from inhabitated areas. The vent pipe outlet shall be covered with a mosquito net.

Chlorination equipment piping shall be secured to the wall by brackets with a minimum clearance of 100mm off the walls for painting and maintenance purposes.

310.11 SYSTEM START-UP

The procedure for putting chlorination equipment into service shall include:

- A bacteriological and physico-chemical analysis of the water to be disinfected.
- Determination of the chlorine demand of the water to be disinfected based on break point method.
- Adjustment of the chlorinator capacity to achieve, after 30 mins of chlorine to water contact a residual concentration of 0.5 mg/l. A check shall be made by measurement of the concentration of free chlorine in water at a pre-determined location in the water distribution system.

In the case of a chlorinator controlled by an automatic residual chlorine measuring device, the indicated concentration shall be checked against the result of an analysis of residual chlorine in the water sample.

310.12 DISINFECTION CONTROL

Following start up of the chlorination system the contractor shall take five samples of disinfected water at five different locations situated at representative distances from the chlorination point so as to achieve effective control of the quality of disinfected water. The following tests shall be undertaken.

- Measurement of free chlorine (Type b1)
- Measurement of free chlorine in water.

310.13 SITE PROCEDURES AND TRAINING

310.13.1 General

Training should be carried out with emphasis being given to safety precautions and methods of dealing with emergencies. Particular attention should be given to the following aspects:

(a) the hazards and characteristics of the material;
(b) safe methods of plant operation, including handling of the connection to supply systems;
(c) methods of maintenance;
(d) special operations; for example, plant shut down and start-up, methods of isolation and preparation of equipment for periodic maintenance and inspection;
(e) the location and operation of emergency shut-off valves;
(f) the procedures to be followed if releases occur;
(g) training in the use of all personal protective equipment supplied.

310.13.2 Operating Instructions

The operating instructions should cover each process operation. Written operating instructions are required, in English and Arabic, for all routine and emergency operations, ranging from guide cards for simple operations to complete manuals.

Copies of the instructions, which should include a flowsheet and indicate valves to be closed in an emergency, should be available in the working area for operators.

310.13.3 Emergency Arrangements

The emergency procedure should include how gas releases may be dealt with safely by site personnel. The procedure should cover various degrees of emergency and should be either supplied in written form or made available to employees so that they know the steps they are required to take. This procedure should include first aid and evacuation arrangements.

310.14 TESTS ON COMPLETION

The tests on completion of the chlorination system shall include the following:

1. Injection rate
2. Injection pressure
3. Absence of leaks
4. Injected concentrations
5. Compliance with specification
6. Safety criteria
7. Such other tests as the Engineer may determine.

310.15 NEUTRALIZATION CHAMBERS

Where specifically called or deemed necessary, a neutralization chamber shall be provided. For safety considerations a chlorine leak detection and neutralization system shall be provided with a capacity to treat the chlorine fumes of the largest full chlorine container present at the site. The neutralization system shall have adequate absorption stages operating under negative pressure (vaccum) including all ducting. It shall consist of the following:

1. A fan to extract the chlorine-laden air;
2. A neutralization tower with contact rings, mist eliminator, and vent system;
3. Necessary neutralization and water recirculating pumps, nozzles, sprayers, piping, valving, etc...
4. A storage tank for the neutralization solution and required chemicals;
5. Necessary ducting, piping, valves, fans, and miscellaneous appatenances;
6. Electric and Mechanical auxiliaries for monitoring instrumentation and control.

The neutralization system shall be capable of treating chlorine gas release at a rate of 45Kg/min with an overall efficiency performance of 99.998 percent removal of the chlorine vapor in the vent discharge.

The scrubber system shall run until the gas concentration in the chlorine storage room is reduced to 1 ppm in less than an hour.

The leak detector and the extractor fan inlets shall be positioned at floor level in the storage premises. The chlorine storage units, the evaporator-chlorinator assembly, and the leak neutralization tower shall be located in separate rooms. In the event of a chlorine leak in the premises where the chlorine cylinders are located, a chlorine leak detector shall sound an alarm lock up the ventilation fans and automatically start the fan that extracts the air from the polluted places to the neutralization tower. The chlorine laden-air flows shall go through the mass of contact rings in the opposite direction to the neutralizing solution. The chlorine neutralization system shall be capable of neutralizing the volume of the largest full chlorine container present at the site.

PART 4

ELECTRICAL WORKS

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401. GENERAL ELECTRICAL SPECIFICATION REQUIREMENTS

401.1 ABBREVIATIONS

The following abbreviations are used in these documents :

1/head/day	liters per head per day
AC	Asbestos Cement
AGMA	American Gear Manufacturer's Association
AOD	Above ordnance datum
BS	British Standard
CDR	Council for Development and Reconstruction.
CFM	cubic feet per minute
Ch	Chainage
CMR	Continuos Maximum Rating
CP	Code of Practice
CPU	Central Processing Unit
DI	Ductile Iron
DIN	Deutsch Industrie Normen
DOV	Double Orifice Valve
DPSK	Differential Phase Shift Keying
DTU	Documents Techniques Unifiés
EDL	Electricity of Lebanon
EMC	Electromagnetic Compatibility
EOH	End of hole.
FDS	Functional Design Specification
FIDIC	Federation Internationale des Ingénieurs- Conseils
FSK	Frequency Shift Keying
g	acceleration due to gravity ($9.807 m/s^2$)
GL	Ground level
gpm	gallons per minute
gr	gram
GRP	Glass Reinforced Plastic
GTSD	General Technical Specification Document
hr	hour
I/O	Input / Output
IEE	Institute of Electrical Engineer
ISO	International Standards Organization
ITS	Institute of Technical Studies
kgf	kilogram force
kPa	kilo Pascal
kVA	kilovolt-ampere
kW	kilowatts
kWh	kilowatt hour
LED	Light Emanating Diode
m	meters
m/s^2	meters per second per second
m^3	cubic meters
m^3/day	cubic meters per day
MDPE	Medium Density Polyethylene
mgd	million gallons per day

mhd	meters head
mm	millimeters
NFE	Normes Françaises - (Electrical)
NLQ	Near Letter Quality
NPSH	Net Positive Suction Head
PS	Particular Specification
PTT	Poste de Téléphone et de Télégraphe
PVC	Polyvinyl Chloride
PWL	Pumping Water Level
RAM	Random Access Memory
RBC	Rotating Biological Contractor
RTR	Reinforced Thermoplastic Resin
RTU	Remote Terminal Unit
SCADA	System Control And Data Acquisition
SOV	Single Orifice Valve
SPTD	Signal Pole Double Throw
SSU	System Supervisory Unit
SWL	Static Water Level
TDH	Total Dynamic Head
TDM	Time Division Multiplex
TEFC	Totally Enclosed Fan Cooled
UHF	Ultra High Frequency
UPS	Uninterrupted Power Supply
UPVE	Unsaturated Polyvinyl Chloride
VDU	Video Display Unit
VGA	Video Graphics Array
VHF	Very High Frequency
VHS	Video Home System

401.2 APPLICABILITY

The following clauses specify general electrical requirements and standards of workmanship for the equipment and installations. General specification clauses shall apply where appropriate except where particularly redefined in the individual specification clauses.

401.3 INSTALLATION STANDARDS

All electrical work must be carried out by a contractor in possession of a current license acceptable to the client which will permit the contractor to carry out work on high voltage and low voltage equipment and cabling.

All works shall be carried out in accordance with the requirements of:

i. ISO, DIN, AFNOR - Mechanical equipment

ii. The institution of Electrical Engineers (I.E.E.) regulations for the electrical equipment CEI, UTE, VDE, AFNOR, BS.

iii. British Standards Institution (B.S.I.) and code of practice (C.P.) or equivalent international electro-technical commission (I.E.C.).

401.4 MATERIALS

All materials incorporated in the works shall be the most suitable for the duty concerned and shall be new and of first class commercial quality free from imperfection and selected for long life and minimum maintenance.

The use of dissimilar materials in contact shall be avoided, but where unavoidable these materials shall be selected so that the natural potential difference between them does not exceed 250 million volts. Electro-plating or other treatment of contacting surfaces shall be employed as necessary to reduce the potential difference to the desired limit.

All materials and material finished shall be selected for long life under the site conditions detailed in the specification and shall be derated by the approved factors given in the British Standard Specifications.

401.5 WORKMANSHIP

Particular attention shall be paid to the appearance of the electrical installation, arrangements of which shall be agreed by the Engineer’s representative before the commencement of installation. The Contractor shall ensure that the installation is completed to the highest standard of neatness with respect to the visible cable runs and the arrangement and alignment of apparatus and fittings.

Conduit shall be surface run with the exception of personnel, administration and control room where, generally, fittings shall be suitable for flush installation.

The positions of all equipment should be detailed on arrangement drawings, indicating the exact position of all equipment and conduit runs.

The Contractor shall be responsible for the fixing of all switches, fuseboards switchboards switchgear, cables, fitting, cable trays, accessories and all other items comprising the electrical installation. No work shall commence until approval of the electrical general arrangement drawings has been given by the coordinating Engineer, the Engineer and were appropriate, the relevant authority.

No structural steel, timber work or concrete shall be drilled for the support of cables or fittings without the prior approval of the Engineer’s representative.

Should the Contractor propose to use junction boxes in auxiliary control cable circuits for the purpose of marshalling a number of cables feeding to a common item of equipment full details shall be given to the Engineer, and the Contractor shall only proceed after the receipt of the Engineer’s written approval. Any such junction box shall be of the wall mounting weatherproof pattern (IP55) with double terminals. All cores shall be ferruled and identified in accordance with the system schematic and cable diagrams.

The Contractor shall arrange for the switchgear and panel manufacturers to provide skilled labour for the supervision of off-loading, placing in position on prepared foundations, erection and commissioning of all switchgear and control panels.

401.6 SAFETY INTERLOCKS

A complete system of interlocks and safety devices shall be provided as necessary for the safe and continuous operation of the plant in order to provide for:

i- Safety of personnel engaged on operational and maintenance work on the plant.

ii- Correct sequence of operation of the plant during start up and shut down.

iii- Safety of the plant when operating under normal or emergency conditions.

interlocks shall be preventive and not corrective in operation.

The Contractor shall be responsible for the preparation of interlocking schemes for the approval of the Engineer.

401.7 PLANT OPERATION

The plant will be unattended and all constituent units shall be arranged to be fully automatic and maintained ready for service at all times.

In order to simplify operation and maintenance, all control schemes shall, as far as possible, follow the same operating pattern, have similar control cubicle layouts, and employ similar items to minimise spares holdings.

Electrical system design shall reflect the hydraulic system design as far as possible and shall be directed to making each major item of plant capable of running substantially independent of others. Where common equipment is employed then every effort shall be made to ensure that no single fault can affect the entire plant and particular care must be taken to protect the overall integrity of the system.

Provided that the principle of segregation is not infringed, solid state or microprocessor based equipment may be incorporated within the various control panels in lieu of electromagnetic relays, timers, etc., in order to perform the necessary control functions. In this event, full details of the proposal to achieve segregation shall be submitted for approval with the Tender. All costs for programming, setting-up, proving and training of purchasers staff in the operation and maintenance of such equipment shall be separately identified in the Schedule of Prices.

401.8 POLARITY

The polarity of all apparatus used for the works specified shall be arranged as follows:-

i. For two poles apparatus, the phase or “live” pole at the top (or left hand side) and the neutral or “earthed” pole at the bottom (or right hand side). On plug and socket outlets, the polarity shall conform to BS 196, BS 546, and BS 1363 as appropriate.

ii. For three or four pole apparatus, the phases in the order L1, L2, L3, and neutral reading from top to bottom or left to right in the case of vertical and horizontal layouts respectively. These layouts are when viewing the apparatus from the front.

All cables shall be connected between main switchboards, distribution board plant and accessories so that the correct sequence of phase identification is preserved throughout the system.

All cables cores shall be identified with phase references. Where more than one phase is incorporated on a common system in one room, then the live cores shall be identified as appropriate and fittings and switch accessories shall permanently labeled and segregated in accordance with the relevant clauses of the I.E.E. regulations.

401.9 FAULT LEVEL

Where a switchboard is directly connected to the low voltage side of a transformer or transformer without any distribution cut-out, then the complete switchboard shall be manufactured to comply in total, with a short circuit rating of 44 (K.A.) for a duration of 1 second minimum.

All small wiring for controls, voltmeter supplies, etc., that originate from the main and sub-main busbars shall be protected by means of busbar mounted H.R.C. cartridge fuses suitably rated for the purpose intended. The maximum size of fuse used shall not exceed 20 amps.

401.10 SUPPLY INTERRUPTION

To ensure that the effects of incoming electricity supply disruptions have minimal effects on pumping capacity, main switchgear shall be fitted with overload, overcurrent and earth fault protection. The switchgear shall not require manual resetting or closing after a supply interruption. Where contactor controls are used for main and auxiliary transformer circuits, these shall be latched so that they are re-energised when the supply is restored.

Re-starting of main motor circuits under automatic control shall be staggered to reduce system disturbance. (See Pump Duty Control.)

401.11 ELECTRICITY SUPPLY SECURITY

Works or pumping stations shall be provided with single or duplicate electricity supplies to a level of security determined by the Purchaser's operating principles and practices, as specified herein.

Duplicate supplies shall be derived from different sections of the supply system network.

Alternative or additional security may be specified by the provision of on-site stand-by generating capacity.

401.12 VOLTAGE DROP

The volt drop within the installation shall not exceed a value suitable for the safe functioning of any fixed current-using equipment.

401.13 EQUIPMENT AND CABLE RATINGS

All busbars, cables, switchgear, fuses, motor starters, relays, instruments, panel wiring, etc. shall be sized and rated in accordance with normal operational requirements of the associated plant and equipment, taking into account maximum load currents, voltage drop, frequency of motor starting, maximum ambient temperature, etc.

Where specific voltage or current ratings have been included on the Drawings and in the description of individual items of equipment in the Specification and/or Bill of Quantities the values stated shall be deemed to be <u>minimum</u> values. It shall however be the responsibility of the Contractor to ensure that all equipment supplied is properly insulated and adequately rated to handle operational loads and, in the case of fuse gear and circuit breakers, to deal with prospective fault currents.

402. EQUIPMENT

402.1 ELECTRICAL PANELS

402.1.1 Switchboard Motor Control Centres

All L.V. and H.V. switchboards and motor control centres shall conform to the relevant British standards and consist of cubicles of equal height and depth mounted side by side to form a composite board of uniform and pleasing appearance.

All L.V. switchboards and motor control centres shall be manufactured by a single, approved, supplier and the construction of each individual panel shall be such that all components shall be selected for standardisation.

L.V. motor control centres shall comply with the requirements on BS5486 (I.E.C. 439) Class 3 of the National Appendix in order to provide fully segregated self-contained compartments. Fully type tested designs only shall by considered.

Switchboards shall be so positioned that access thereto is not obstructed by the structure or contents of the building. A distance of not less than 900 mm shall be provided and maintained in front and at the rear of every switchboard/panel for the purpose of safety and effective operation and adjustment of all equipment mounted thereon, and space and access behind switchboard/panels shall be sufficient for adequate service, but in no case less than 900 mm.

Where a switchboard incorporates rack-out switchgear, doors or hinged panels, there shall be a clearance of not less than 1200 mm. between any wall or immovable structure and the switchgear, doors or hinged panels when it is in the racked-out or open position.

Rear access switchboards and panels shall be provided with unhinged lift-off panels only. Hinged panels will not be permitted.

All apparatus shall be positioned on a switchboard so that there is ample room for its safe and effective operation and handling.

Each individual switchboard, motor control centre shall be provided with 3 no. socket outlets. They shall be installed to facilitate connection of test equipment (220 V) portable tools and inspection load (110 V). Each socket shall be provided with a colour coded cover and matching colour coded plug.

Each section shall be fitted with a demountable undrilled metal gland plate positioned at low level but with adequate space for termination of cables, conduits, etc. The gland plates shall be efficiently earthed to the panel earthing system by a separate earthing conductor. The base of the panel shall be provided with removable plates of the split type to seal the cable/conduit entry cut-outs. The plates shall be positioned directly below the gland and base plate shall be of non-ferrous material.
Switchboard and motor control centres shall be suitable for mounting on concrete plinths.

All foundation holes shall be at least 75 mm from any outside edge of the panel and at least 75 mm from any concrete edge to avoid break-out when tightening bolts.
All lifting eyes supplied with the boards shall be removable and replaced, at site, with chrome plated screws.

Each panel shall be treated in accordance with the metal protection requirements. The colour finish of the outside shall be as advised by the Engineer. Cubicle interiors shall be painted white. Colour shades shall be to BS. 4800.

402.1.2 Panel Construction

Panels shall be constructed of sheet steel having a minimum thickness of 2.0mm (14 SWG) or other approved material, and similar equipment shall be of the same manufacture and units of the same type and rating are to be interchangeable. The use of toxic, hygroscopic or flammable materials shall be avoided.

LV Panels shall be damp and dust protected (IP44 for indoor dry or IP55 for indoor humid/wet) situations and hoseproof (IP65) for outdoor or wet situations, or as otherwise specified under the Particular Specifications.

Switchboards shall incorporate a rigid steel frame and be suitable for ready extension at each end without further cutting or drilling. Composite switchboards shall be assembled by the principal electrical manufacturer and shall be sectionalised as necessary to facilitate handling.

Switchboards shall include barriers between each of their units to ensure safe maintenance on any circuit during normal operation with the remainder of the board live. When a functional unit is isolated and open, the degree of protection to any remaining live part shall be at least IP20. Barriers or covers to live components shall have warning labels attached.

If any compartments are provided within a section of outgoing units which are not fully equipped, they shall be arranged so that they can be fully equipped without de-energising that section of the switchboard.

Cubicle type switchboards shall be totally enclosed, flush-front and rear pattern, arranged in a multi-tiered formation if practicable, with at least 300mm clearance between floor level and any operational item of fuse gear or control gear. Kicking strip protection shall be provided by a 100mm high plinth forming the base of the switchboard.

The overall height of control panels, including plinths, shall not exceed 2300mm. Isolator handles, control switches, push buttons shall be centered not more than 1800mm above finished floor level. Indicator lamps and instruments shall be centered not more than 2000 mm above finished floor level.

All components mounted on the front of the panel shall be of matching uniform appearance, orientation and colour, with all bezels and escutcheons finished black. The layout and grouping of components shall be as approved or specified.

Within each control cubicle a reduced size schematic diagram of the control circuit, printed on durable material, shall be permanently fixed.

All cubicles shall be provided with anti-condensation heaters mounted at low level and, with the exception of starter cubicles, they shall be provided with internal thermostats (adjustable type) and externally operated ON/OFF control switches mounted on respective doors. The thermostat range is to be compatible with the location and climate.

402.1.3 Doors and Covers

Each section or compartment shall be provided with full width access doors or covers, with individual doors or covers not exceeding 750mm width.

All doors and covers shall have returned edges for rigidity and incorporate dust seals of flexible material secured in channel rebates. Covers exceeding 0.5m² in area shall be provided with a supporting lip within the lower edge or have lift-off hinges. All doors shall be supported on strong hinges of non-corrodible material and shall be secured by adjustable quarter turn cams, operated by small TEE handles incorporating key operated barrel locking facilities or flush locks with drive key inserts. Covers shall be secured by similar fastenings or captive bolts.

All additional fittings such as handles, hinge brackets and locks shall be a black finish, polyamide moulding or epoxy coated metal.

Doors shall open at least 90° with the opening positively limited such that doors and their appurtenances are prevented from fouling adjacent panels when opened.

All doors shall be fitted with a restrainer, so positioned that each door shall be prevented from swinging more than 120°. Earth leads connected to doors will not be acceptable as restrainers.

402.1.4 Switchboard and Busbars Rating

Switchboard busbars, droppers, switchgear and its associated cable boxes shall be mechanically and electrically designed to withstand the fault level and duration specified herein and (except for LV switchboards rated less than 800A) shall be an ASTA certificated design rated at not less than 80 kA RMS for 1 sec. or 50 kA for 3 sec. LV switchgear and motor control gear shall comply with BS 5486 Form 4 segregation of busbars, functional units and terminal chambers, unless otherwise specified.

Busbars and droppers shall each be air insulated and formed from solid drawn, high conductivity copper bars, having a constant current rating with a uniform cross sectional area throughout their length. Each shall be clearly marked with the appropriate colours to indicate each phase, neutral and earth. Droppers shall be as short and as straight as possible. Busbar compartments shall be fully segregated and shrouded from all other sections of the switchboard.

All busbar connections shall have at least two bolt fixings. Where flexible busbar connections are used these shall be secured by high tensile steel bolts and nuts with anti-vibration locking devices.

402.1.5 Alarms and Indications

Separate indication of the following conditions shall be provided by means of annunciators grouped as indicated on the front of the panel. All indications shall have a lamp test facility.

Alarm annunciators shall be provided with accept and reset facilities together with an audible alarm and an audible/mute selector switch.

Each of the alarm conditions specified shall initiate its individual annunciator with a flashing indication which shall become steady when the "Accept" button is pressed and be extinguished by the "Reset" button once the alarm condition is removed.

In specified unattended locations, self reset facilities shall be provided to enable the system to restore itself to normal operation after the fault has passed.

With the audible/mute switch set to "Audible", the audible alarm shall sound when the indication is flashing and be silenced when the "Accept" button is pressed. In the "Mute" position the audible alarm shall be muted and any alarm initiation shall give a steady lamp indication only.

To prevent false alarms occurring during mains failures or on restoration of mains supply, the common alarms specified shall be supported by a battery backed supply, either directly or via an inverter.

402.1.6 Panel Wiring

Panel wiring shall be run neatly within the cubicle in suitable cable looms or panel trunking, and in the case of instrument, intrinsically safe or safety extra-low voltage circuits, run in separate groups accommodated within the cubicles. The looms or trunking shall be adequately secured without the use of adhesive material. Wiring carried across door hinges shall be neatly loomed and rolled in torsion in the plane of the hinges to minimise flexing of the wiring, thus wiring shall enter and leave at different levels as widely spaced as practicable. Bushings or grommets shall be used where wiring passes through sheet metal or plastic.

All components and auxiliaries in repetitive units shall be wired in an identical pattern to match the arrangement of each component.

Wiring cables shall be adequately rated, tinned copper stranded conductors of not less than 1.0mm² (32/0.20) PVC insulated 600V grade, except wiring to PLC or other light current equipment which shall be not less than 0.5mm² (16/0.20).

Wiring insulation shall be coloured as follows:

AC Circuits
Mains supply (LV) - Black
Uninterruptible power supply (LV) - White
ELV supplies (up to 50V AC) - Yellow
Intrinsically safe circuits - Blue

DC Circuits
Battery supply (ELV, not exceeding 120V DC) - Grey

Where various voltages exist within the above definitions, the colour coding shall be subject to agreement with the Engineer.

Each wire shall be terminated with suitable ring or spade crimps or bootlace ferrules and identified at both ends by means of white or resistor colour-coded ferrules imprinted to correspond with the diagram of connections. Wires linking common points in the circuit shall bear the same reference at each termination. Alternative identification methods require prior approval of the Engineer.

All switchboard and instrument panel wiring shall be carried out in P.V.C. insulated cable, in a neat and systematic way and securely fixed and arranged so that access to the apparatus is not impeded.

Auxiliary wiring shall be run neatly within the cubicle and in the case of instrument circuits, run in separate groups accommodated within the cubicles. The minimum size shall be submitted for the Engineer's approval. Wiring shall be supported in insulated cleats or cable trunking.

All terminal blocks for the connection of small wiring shall comprise shrouded anti-tracking mouldings of melamine phenolic or comparable material within provision for securing conductors either by high tensile screws and clamps or alternatively, in the case of the small telephone type conductor, by solder tag connection.

Terminal blocks shall be arranged to facilitate easy access to both terminals and wiring ends. Connections for outgoing circuits to auxiliary pilot cables shall be provided with test links.

Identification ferrules or reference numbers shall be fitted on the wires at both ends and letters and numbers shall correspond to the appropriate wiring diagram and coded in accordance with I.E.C. 446.

402.1.7 Earthing

All metal cases of meters, relays, instruments, starters, and control switches shall be connected to the switchgear frame earth terminal by means of green and yellow PVC insulated cable, not less than 2.5mm^2 cross section.
An earthing terminal or group of terminals shall be provided in the panel for termination of panel earthing connections and incoming cable earth or connection to a main earth bar.

A main earth bar of copper shall be provided to run the full length of each board so that all cable sheaths and armouring may be bonded to it. Where the fault level at the switchgear is 33kA or less the minimum size shall be 31.5mm x 6.3mm. For short circuit duty in excess of 33kA the size shall not be less than 50mm x 6.3mm.

All live terminals of equipment mounted on cubicle doors and/or enclosure covers shall be adequately screened unless protected by an interlocked isolator. All doors and hinged covers shall be efficiently earthed by a separate conductor.

402.1.8 Panel Preparation and Finishing

The whole preparation and paint system shall be suitable for the operating environment specified and a painting schedule giving details of preparatory treatments, types of paint, number of coats and method of application shall be submitted with the Tender. Proprietary items may be used in their standard finish subject to the approval of the Engineer.

The system proposed shall conform to the following minimum requirements.

After all machining and forming has been completed all steelworks surfaces shall be thoroughly cleaned of rust, scale, welding slag or spatter and other contaminations prior to any painting.

Panels for indoor location shall, immediately after cleaning, have all surfaces protected by an approved zinc-based corrosion resistant primer, followed immediately by one intermediate and two finishing coats of paint to give a minimum total dry film thickness of 50 microns (0.002").

Panels for damp situations or outdoors shall have the surfaces grit blasted and zinc sprayed within 4 hours to BS 2569 Part 1 to a thickness of 125 microns (0.005") at the works. The final paint finish shall be one of two pack epoxy primer and two coats of epoxy paint to give a minimum total dry film thickness of 75 microns (0.003").

Steel fixings and fastenings shall be treated to prevent corrosion by hot dip galvanising to BS 729 or sherardised to BS 4921 Class 1 before painting. Chromed fittings shall not be used.

Any damage occurring to any part of a painting scheme shall be made good to the same standard of corrosion protection and appearance as originally employed. Any finish coat applied on-site shall be considered for decorative purposes only.

402.1.9 Paint Colours

The colours of the primer, intermediate and finishing coats of a paint system shall be easily distinguishable from each other and the materials used shall be suitable for the application employed and preferably be supplied by one manufacturer who shall ensure that all coatings are compatible.

Electrical control panels shall be gloss finished in the following final colours:

DETAILS	COLOUR	BS 4800 Ref:	BS 381C Ref:
Panel Exterior	as advised by the	Engineer	
Interior Equipment	White	10 B 15	-
Trays	White	10 B 15	-
Busbar Shutters	Signal Red	04 E 53	537
Circuit Shutters	Lemon Yellow	10E 53	309

402.1.10 Labels

Individual items not subject to switchboard requirements shall have labels of non-corrodible, Traffolyte sandwich type white/black/white, or yellow/black/yellow for danger labels or as approved by the Engineer. They shall be fixed square to the equipment by means of screws or rivets of nylon or non-corrodible material. Labels affixed with adhesive will not be accepted.

Inscriptions on labels and circuit lists shall be in English and Arabic and be submitted for the approval of the Engineer. The abbreviation `No.` shall not be used.

A list of circuits in approved form shall be supplied and fixed behind a "Perspex" sheet on the inside of all distribution boards which are provided or rewired under this Contract.

Each switchboard shall be provided with a title label and have circuit designation labels fixed to the front and rear cover of each circuit compartment. Rear covers for more than one sub-section shall have labels for each sub-section. In all cases, the label shall be positioned so as to leave no doubt as to which item it refers.

All indicators, instruments, relays, control switches, push-buttons, fuses and other ancillary apparatus shall be provided with labels clearly stating their function.

Character sizes for main title and circuit designation labels shall be at least twice those for ancillary items.

All label inscriptions shall be to the approval of the Engineer and the abbreviation `No.' shall not be used.

Labels fitted to the front of the switchboards/control panels/starters shall be of transparent perspex with radiussed or chamfered front edges, reverse engraved with white infill then sprayed on the rear to match the colour of the board. Other labels shall be sandwich type white/black/white, or yellow/black/yellow for Danger labels, or as approved by the Engineer.

All labels shall be fixed square to the equipment by means of screws or rivets of nylon or non-corrodible material. Labels affixed with adhesive will not be accepted.

All external labels supplied to H.V. and L.V. switchboards and motor control centres and other items where specified, shall be clear perspex, back engraved, filled black and back painted the same colour as the switchboard. All labels shall have chamfered edges and shall be affixed with chrome plated screws. Adhesive labels will not be accepted.

All internal labels shall be engraved multi-layered plastic (Traffolite or similar) affixed with chrome plated screws, adhesive labels will not be accepted.

Each switchboard, control panel, distribution board, compartment door etc. shall have a label and each door mounted component or control shall have a function label.

Every internal component shall be identified and each fuse shall be labelled with identification, fuse type, fuse current.

Compartments with doors not interlocked to an isolator or removable covers having access to live parts shall have an external label affixed thereto : - "DANGER LIVE TERMINALS" black letters on a yellow background.

All other labels shall be in English but space shall be left for additional labels in Arabic to be mounted alongside or directly above unless otherwise instructed.

402.1.11 Warning Signs

`Automatic Plant' warning signs shall be provided and erected by the Contractor in the building or on the plant in a prominent position to be agreed. The 500mm x 300mm x 0.7mm (22SWG) signs shall be located approximately 1.6m above the adjacent floor level to the sign centre.

The sign shall be of 22 swg, vitreous enamelled aluminium sheet or plastic, having black letters on a yellow background, inscribed as follows:

CAUTION

PLANT UNDER AUTOMATIC CONTROL
AND LIABLE TO START WITHOUT WARNING

ISOLATE AT SOURCE BEFORE ATTEMPTING ANY
MAINTENANCE OF MECHANICAL AND ELECTRICAL PLANT

402.1.12 Equipment for Potentially Explosive Atmospheres

Equipment for use in potentially explosive atmospheres shall be selected and installed in accordance with BS 5345, subject to the temperature classification of the specified gas, vapour or liquid. Ex(d) and Ex(i) classified equipment shall be certified for Apparatus Groups IIA and IIB.

In such areas, aluminium and other light metal alloys shall only be used for enclosure of electrical apparatus and fittings where such enclosures conform to the material requirements of BS 5501
Part 1.

Aluminium and light metal alloy fans on motors may be used if adequately protected, or if plastic fans or cowls are used they shall be of anti-static material.
Where no British Standard is applicable, equipment to an equivalent European standard may be submitted, subject to the approval of the Engineer.

402.1.13 Field Mounted Equipment

Individual starters, fuse-switches, distribution boards and other equipment shall be housed in robust, heavy gauge, rustproof, metal-clad enclosures having external fixing lugs except where otherwise specified.

Components, fittings and housings shall be as specified elsewhere in this specification.

Equipment housings shall be mounted such that the terminal and covers are readily and safely accessible and are not obstructed or affected by the adjustment or mounting arrangement.

i) Push button stations shall be single or composite units suitable for accommodating the required buttons in the above enclosures. Each button top shall be fitted with a durable protective flexible boot.

ii) Junction boxes shall be equipped with rail-mounted, feed-through terminals adequately sized to accommodate the cables to be terminated. An earth connection facility shall be provided for each box.
Surface junction boxes used to connect power cables for submersible pumps shall be equipped with busbars of adequate rating as specified in the “Switch board & Busbars rating” paragraph. The busbars shall be drilled to accommodate all necessary terminal lugs. Adequate glands and gaskets shall be used to maintain the junction box with an index of protection of IP67.

iii) Auxiliary switches shall be mechanically and electrically suitable for the duty and circuit operations specified herein and intended by the switch manufacturer. Roller-lever operated switches shall be of the snap action type.

Where employed for crane or gantry duty, spring failure within a limit switch shall not render it inoperative.

Hand-gear interlocks shall be fitted to any driven equipment which has provision for manual operation to ensure that it is not possible for drives to start with the hand-gear in position.

402.1.14 Cabling Facilities

Cable boxes and glands shall be accommodated within the cubicles except where otherwise approved and all removable access, sealing and gland plates are to be provided with gaskets to form an adequate seal against the external atmosphere.

Adequate space within each compartment shall be allowed for external cable tails to be connected without stress on the terminations, bearing in mind the type and size of such conductors. Where multicores in excess of $95mm^2$ or any single core cables are to be terminated, a minimum distance of 450mm free space shall be allowed between the gland plate and the terminal connection point.

In multi-tier compartments, individual terminal covers and gland plates shall be provided for each circuit such that additional circuits may be terminated safely whilst the switchboard is energised.

For paper insulated cables, a suitable cable end sealing box shall be provided for each circuit as specified. Where the cable enters from beneath the panel, the bottom of the wiping gland shall be at least 150mm above the panel floor level. Removable split sealing plates are to be provided for subsequent fitting around such cables.
Un-drilled removable gland plates shall be provided for cables requiring compression glands entering from beneath the panel. The plate shall be located at least 300mm above the panel floor level and shall form part of a compartment constructed within the panel to seal the interior from the exterior of the panel. Access for glanding-off shall be provided by removable covers fitted to the available vertical sides which may extend the full width of the panel as necessary.

Where single core cables are to be accommodated, a non-magnetic or slotted gland plate shall be provided.

Terminals, studs or drilled holes shall be provided to accommodate all necessary cable terminal lugs and, prior to manufacture, the Contractor shall confirm cabling termination requirements with the Engineer.

402.1.15 Terminals

All terminal blocks for the connection of small wiring shall comprise shrouded anti-tracking mouldings of melamine phenolic or comparable material with provision for securing conductors either by high tensile screws and clamps or by solder tag connection.

Terminal blocks shall be arranged so that both terminals and wiring ends are readily accessible and have separate terminals provided for incoming and outgoing wires, together with insulated barriers between adjacent connections and transparent insulated covers. Blocks accommodated on common mounting rails shall have a foot designed to ensure a secure fit to the rail. Foot springs shall be of stainless steel and have a locking device fitted to prevent accidental release of the block.

Each terminal shall be labelled to correspond with the diagram of connections and terminal identification labels shall be attached to the fixed portion of the terminal blocks only. Terminals for intrinsically safe circuits shall be clearly segregated and coloured blue.

Terminals which may be `live' when the equipment is isolated from the main supply shall be adequately shielded from accidental contact and be clearly identified and inscribed accordingly.

All terminal boards and terminal blocks shall provide a positive mechanical clamp type connection. Pinch screw type terminals shall not be used. Terminals for the connection of all external cabling shall be situated at least 100mm from their respective gland plate or further if the cable size requires a greater distance for dressing.

All main phase terminals shall be suitably marked to ensure correct phase identification

402.1.16 Insulating Mats

Black rubber matting shall be supplied complying with BS 921 shall be supplied for all indoor control or switch gear panel. It shall extend the complete length of the control panel and the minimum width shall be one metre.

402.2 TRANSFORMERS

402.2.1 Current Transformers

Each current transformer shall bear a label showing the ratio, class, short time factor and accuracy limit factor. The inscription must be readable when the transformers are installed within the gear without the necessity of dismantling any equipment other than removing cover panels.

Bar type current transformers shall be supplied in preference to those with wound primaries. Short time current factors shall relate to the full fault level specified. For over-current protection, the product of VA rated burden and rated accuracy limit factor shall be 150 unless otherwise agreed with the Engineer.

One secondary terminal of each current transformer shall be earthed at the switch-gear.

402.2.2 Voltage Transformers

Voltage transformers shall be vacuum impregnated or encapsulated resin insulated type. Each transformer being fully isolatable and accessible for maintenance purposes and fitted with primary and secondary fuses.

402.2.3 Control Transformers

Each motor starter shall be provided with a single phase low voltage transformer to supply the operating control circuit.

Primary windings shall be suitable for 220 volts single phase supply and be complete with control fuse and neutral link. Secondary windings shall be suitable for 110 or 220 volt supply, centre tapped earth (55-055 volts) and protected by a suitably rated fuse fitted to each pole.

Transformers shall be adequately rated for each starter control circuit and generally comply with BS. 3535.

402.2.4 Low and Extra Low Voltage Supplies

Where low and extra low voltage supplies are required for illumination and power supplies (hand lamps, installations liable to flooding portable hand tools, etc.) they shall be obtained from suitable transformers mounted within each switch-gear control panel or distribution cubicle.

These units shall be of the non-inherently short circuit proof type and shall have primary and secondary fuses mounted in an accessible position. All fuses shall comply with the Fuses requirements.

402.2.5 LV Outlet Transformer

Isolating transformers shall be of air cooled, double wound construction in accordance with BS 3535, fitted with an earthed metallic screen between primary and secondary windings and suitable for operation from a 220V 50HZ single phase supply.

The secondary winding shall have a rated output of 100VA continuous (1500VA intermittent tool rating) at 110V and have a centre tapping connected to earth.

The transformer shall be enclosed in a wall mounting sheet steel or moulded casing with external fixings lugs and separate cabling connections. The secondary output shall be via fuses incorporated in the enclosures.

402.2.6 High Voltage Transformers

402.2.6.1 General

The transformers will be used for distribution purposes on electrical power and lighting installations as specified.

Each transformer shall comply with the requirements of BS 171 for outdoor, naturally cooled types, having an insulation level in accordance with Part 3, Table II List 2.

They shall be mineral/silicone oil cooled or dry type/cast resin as specified and shall operate satisfactorily at any supply voltage between ± 15% of the rated voltage as specified herin, and within ± 2.5% of 50Hz. Simultaneous variations in voltage and frequency will not be in opposite directions.

All connections between the transformer coils and the items mounted on the enclosure shall be provided, adequately braced and supported to withstand the specified fault conditions.

402.2.6.2 Tappings

Tappings at ± 7% and ± 15% nominal voltage shall be provided on the HV windings as specified herein, preferably arranged at positions in the coils to preserve the electro-magnetic balance of the windings at all voltage ratios, and the transformer shall give its full rated output on any tapping.

In any dual voltage units, the changeover facilities shall be by means of internally mounted, off-load links within the enclosure.

402.2.6.3 Tapping Switch

An externally operated, off-circuit tapping switch of robust construction shall be provided, especially designed against risk of damage from short circuits and having all contact surfaces of ample area for satisfactory operation during overloads.

The mechanism shall be hand-operated and shall come to rest only when the switch is making full contact, giving clear indication of the ratio at which the transformer is operating. The switch shall operate simultaneously on all three phases.

Approved means shall be provided for locking the tapping switch mechanism in the positions corresponding to each voltage ratio.

402.2.6.4 Rating and Identification Plates

Each transformer shall be provided with a terminal marking and rating plate, together with a distinguishing number plate of approved type bearing a specified designation reference in raised characters not less than 75mm in height.

402.2.6.5 Construction

The core shall be built up of interleaved laminations, stepped to give optimum magnetic contours and insulated on one side, of cold reduced, grain oriented silicon steel working at a flux density not exceeding 16,500 lines/sq.cm (1.65 Tesla). Corner and yoke joints shall have minimum gaps for quiet and efficient operation and shall be securely clamped and braced with channel section frames to reduce vibration.

Oil filled enclosures shall comprise a tank of sheet steel construction incorporating facilities for lifting and jacking the complete units and have a channel section skid base fitted with rollers. Holes shall also be provided in the skid base at each end for haulage purposes such that, after installation, the rollers may be re-located therein and the transformer will stand on its base.

Cooling shall be by means of flange mounted radiators. Top cover plates shall be weld sealed for ratings up to 800kVA. Ratings of 1000kVA and above shall have gasketted removable top cover plates.

All flanged joints shall have gaskets of suitable non-absorbent material to prevent entry of water or leakage of coolant.

Each tank shall be provided with a flanged drain valve (minimum 1" BSP) fitted with a blanking plate. All valves shall be of gunmetal and the sluice type with internal screw, unless otherwise approved.

402.2.6.6 Painting

All associated enclosure steel work to be shot blasted on completion to ensure freedom from welding slag, rust or grease prior to spraying.

Oil filled tank interiors shall be given a high quality coolant-resisting, anti-corrosion finish coating.

The outside of the tank shall be covered with a minimum of 3 coats of paint, consisting of primer, intermediate and final high gloss, weather resistant finish, applied by the flooding process to ensure complete coverage of tubes and areas inaccessible to brush and spray.

402.2.6.7 Earthing

The core and any conductive parts of any protective enclosure shall be earthed by means of substantial connections to a common terminal provided for this purpose. An earthing terminal stud not less than 12mm diameter, complete with brass nuts and washers, shall be provided at the base of each transformer for connection to the external earthing system.

402.2.6.8 Cable Terminations

Terminal boxes shall be provided suitable for connecting the external cables specified herein and terminal assemblies shall be capable of withstand and the specified prospective fault rating. Where single core cables are to be accommodated, a non-magnetic or slotted gland plate shall be provided.

402.2.6.9 Link Boxes

Where PILC cables are terminated in compound filled boxes, disconnecting link boxes shall be provided to enable tails to be pressure tested without the need to remove cables. Links shall be of the bolted type and should be readily accessible without disturbing the cable connections or the transformer enclosure.

402.2.6.10 Oil Gauge

A gauge of adequate size shall be fitted to indicate the oil level at 15°C and when the temperature has risen to the limit permitted by BS 171. The level in the gauge shall be clearly visible from the ground and the gauge shall be protected against accidental damage.

402.2.6.11 Thermometers

A dial type indicating thermometer shall be provided and mounted on the side of the enclosure for ease of reading arranged to measure the temperature in the hottest areas of the transformer coolant or winding. This may incorporate the temperature protection requirements specified below.

Oil cooled transformers shall be provided with a thermometer pocket in the tank and a thermometer to register the coolant temperature. The pocket shall be fitted with a protective thimble when not in use.

402.2.6.12 Protection

The following protective facilities shall be provided as specified for each transformer. All switches contacts shall be rated at least 125V 0.5A DC.

Restricted earth fault protection shall be arranged such that the star connection of the secondary windings shall be earthed via an air insulated, removable link which will accommodate a current transformer provided by the switch-gear manufacturer. The CT shall be provided with adequate supports and terminating facilities and both the link and CT shall be housed in a box with a removable cover. The box shall have a 20mm ET threaded entry for the CT cable.

i) Sealed type transformers shall be fitted with a spring-loaded self resetting pressure relief device actuated by excess pressure within the transformer tank. The setting shall be suitable for application with the coolant used and actuate a manually resettable switch to initiate a remote trip.

   Over-temperature protection shall be provided by means of a scaled dial indicating thermometer fitted with two adjustable contacts arranged to initiate a remote alarm and trip circuit respectively.

ii) Aspirated type transformers shall be fitted with an oil sealed de-hydrating breather of the visible indicating pattern.

   Over-temperature protection shall be provided by means of a scaled dial indicating thermometer fitted with two adjustable contacts arranged to initiate remote alarm and trip circuits.

Transformers having a conservator shall be fitted with a Buchholz gas and oil actuated protective device of approved make. The protector shall be of the double float pattern with both alarm and trip contacts, an inspection window and a terminal box suitable for conduit entry. A petcock shall be provided at the top for the release of gas and a second petcock fitted at a lower level for testing the operation of the relay by compressed air.

402.2.6.13 Conservators

Oil filled, aspirated transformers rated in excess of 2MVA shall be provided with a conservator vessel fitted with a sump and suitable means of drainage. The oil connection to the transformer tank shall project at least 50 mm vertically inside the conservator and the oil sight gauge fitted to conservators shall be arranged to indicate oil in the conservator tank only when the oil connection to the transformer tank is submerged.

The transformer top plate shall be removable without disturbing the conservator mountings or connections.

402.2.6.14 Drying out and Filling

Each transformer shall be dried out and filled to normal working level with coolant at the manufacturer's works. It shall be transported, installed and put into service without the necessity for further drying out on site.

402.2.6.15 Dry Type Transformers

For indoor use only and where specified, dry type transformers shall comply with all the proceeding clauses except that:-

i) **Coils:** The windings and impregnation shall be designed to minimise stresses induced under normal and abnormal circuit conditions. Assembled coils shall be impregnated under high vacuum with epoxy resin and cured to relieve stress, prevent voids and be non-hygroscopic.

The coils shall be located concentrically and firmly on their formers with allowance for axial movement due to temperature changes. All air ways shall be smooth and un-obstructed.

The core frame shall incorporate lifting lugs and be mounted on a base frame having towing holes and cross members for stability.

ii) **Enclosures:** They shall be ventilated housings formed of fire resistant building materials, glass fibre moulded panels with steel mesh

reinforcing or sheet steel panels, providing a minimum protection to IP 21 against water and accidental contact. Access doors for maintenance shall be provided and interlocked with the controlling HV and LV switch-gear to prevent access when either switch is closed.

The construction, preparation and painting details for sheet steel panels and doors shall be as specified under the switch-gear requirements.

iii) **Protection**: Over temperature protection shall be provided by thermistors located in the three phases of the LV coils. These shall be set to suit the operating characteristics of the transformer, one set to provide a high temperature alarm and a second set to provide a higher temperature trip.

Where enhanced cooling by fans is specified, additional thermistors shall be provided for switching control of such fans.

All thermistors shall be wired to relays housed in a box mounted externally on the enclosure. The box shall include suitable terminals for external cabling, a 20mm ET threaded entry and a removable cover.

402.3 SWITCHES

402.3.1 Switches

Switches shall be of the air break pattern, enclosed in zinc sprayed heavy duty, cast metal or sheet steel cases providing enclosure protection to at least IP55 unless otherwise specified, suitable for industrial surface mounting or flush cubicle mounting as specified.

They shall be rated in accordance with BS 5419 or equivalent and be fitted with solid or HRC fuse links as appropriate in each phase and a neutral link, all contained within the switch case, with the terminals accessible from the front of the switch. Phase barriers and contact shrouds shall be provided with an interlock to prevent withdrawal or access when the fuse switch is in the `ON' position.

Each switch shall have a free handle control mechanism to prevent inching and damage to contacts, be fitted with `ON' and `OFF' position indicators and have provision for locking in the `OFF' position. When padlocked in the `OFF' position, interlocks shall prevent the unit door being opened.

The moving contacts of fuse switches shall be readily withdrawable as a complete unit for maintenance when the remainder of the board is live.

The compartment isolating switch shall interrupt all supplies into the compartment to enable safe maintenance to be undertaken. Isolators shall have robust handles and means shall be provided to enable the isolator to be padlocked in the OFF position only. One padlock with 4 keys shall be supplied for each isolator on the board.

402.3.2 Push Buttons

Push buttons shall be heavy duty, double break pattern with fully shrouded moulded buttons having a spring return action through a flexible oil-tight seal. Each button shall be coloured in relation to its function in accordance with Appendix 2 or as otherwise specified herein and bezels shall be coloured black.

Emergency stop buttons shall be arranged to de-energise without delay the drive motors for the whole of the associated plant whatever control mode of operation may be selected. They shall be of the `stay-put' type having a large red mushroom head with twist-to-release manual reset, suitably labelled and have at least two poles, 1 N/O and 1 N/C with contacts suitable for the circuit operation.

Where key reset heads are required, the key shall be common for all buttons.

402.3.3 Selector Switches

Selector switch shall be mounted on the front of the panel; The switch shall be lockable in each position by means of a barrel locking device incorporated in the handle and the switch handle shall clearly indicate the switch setting.

402.3.4 Emergency Stops

Where means of stopping are required adjacent to a motor or the driven plant to prevent danger, emergency stop push buttons, trip switches or interlocks shall be provided, arranged to immediately isolate the supply, so long as a greater risk is not thereby introduced.

In automatic control schemes, emergency stop buttons shall have a stay-put lock off feature, with "twist to release" manually operated reset facility. Such a button shall be located on the motor starter panel. A key operated reset facility shall be provided where emergency button is located at the plant.

Where plant is normally enclosed or has fixed guards to prevent accidental contact from moving parts, stop buttons are not normally required adjacent to such parts.

Stop buttons shall be hard wired direct to all motor control circuits and not by way of any semi-conductor logic control circuitry.

Means of equipment isolation for maintenance purposes shall be provided. This may be either by use of key operated emergency stop buttons or lockable isolators, which may be at the control panel or local to the plant.

402.3.5 Auxiliary Switches

Auxiliary switches for indicator, protection, interlocking and supervision purposes shall be readily accessible and enclosed in a transparent dust proof cover.

Adequate secondary disconnection shall be included between the fixed portion of a circuit breaker and the moving portion.

Spare auxiliary contacts, two normally open and two normally closed, shall be provided on each unit and wired to suitable spare terminals.

402.3.6 Low Voltage Fuse Switches

Fuse switches shall comprise flush mounted, heavy duty, composite air break switches with fuse units complying with BS. 5419 and fitted with fuses to BS.88 and shall be rated for the design load.

Composite units shall be contained within an enclosure of metal and shall be fitted with an earthing terminal or equivalent to enable the enclosures to be earthed irrespective of any means of connection, such as is provide for attaching armouring or other metallic covering of the cable supplying the composite unit.

The enclosure shall be so constructed that the cover cannot be opened until the switch is fully opened and that when the cover is opened, a competent examiner can override the interlock and operate the switch. After such operation, the cover shall be prevented from closing with the switch position indicator in a false position.

Switches shall be provided with mechanical ON/OFF indicators and operating handles. Means shall be provided for locking the switch in the OFF position only.

The fuse shall either include a suitable fuse carrier or it shall be capable of isolation. If the fuse carrier is included, it shall be such that when it is being withdrawn normally or when it is completely withdrawn, the operator is completely protected from accidental contact with any live metal of its fuse link, fuse contacts and fixed contacts.

If the fuse is capable of isolation, it shall be so interlocked with the switch that isolation is complete before the fuse enclosure can be opened; further the switch shall be prevented from closing while the fuse cover is open.

402.4 RELAYS

402.4.1 Control Relays

Control circuit relays for switching 5A/250V or less shall be of the multi-pin plug-in type having the following features:

- Neon or LED indication of relay energisation;
- mechanical ON/OFF indication;
- manual test button with provision for retention of the button in the operated condition for test purposes;
- legend plates on relay and base;
- relay retaining clip;
- be mounted on moulded bases having recessed screw terminals.

If sufficient contacts are not available in one relay, not more than two relays may be connected in parallel.

Any relay used to switch an external alarm circuit shall have a volt-free contact for the purpose.

402.4.2 Protection Relays

Protective relays shall be provided, for fault and overload protection, to operate L.V. circuit breakers.

All protective relays shall conform to the latest edition of BS. 142 and be manufactured by an approved international manufacturer. They shall be suitable for climate and site conditions and fully sealed against the ingress of moisture and dirt.

Each relay shall be complete with panel mounting facilities and terminals for external circuit connection.

Electro-mechanical protection relays and associated devices shall be provided as specified, suitable for flush mounting in dust proof cases; withdrawable types being provided where they are fitted in fixed panels.

402.5 FUSES

402.5.1 Fuse Links and Holders

Suitably rated fuses shall be provided at all points necessary for circuit protection and isolation, separate fuses being provided for instruments, indication, alarm, heater and coil circuits. Fuse ratings shall be rationalised as far as possible to limit spares.

i) LV fuses in circuits exceeding 50V shall, where practicable, be housed in all-insulated carriers with fully shrouded bases of matching colour, which shall not be interchangeable with carriers and bases provided for removable solid links which shall be coloured white.

   LV fuse links shall be HRC cartridge type to BS 88, Class Q1, having provision for screw fixings for attachment to the carrier.

ii) Control and Instrument fuses may be accommodated in moulded terminal blocks suitable for DIN rail mounting. Fuses rated up to 6.3A 250V shall be 20x5mm (G type DIN 41660) having a hinged fuse carrier housing.

   Fuses rated up to 13A 250V shall be 25 x 6.3mm cartridge type to BS 1362, secured by a screw cap. The live connection being made to the lower terminal.

A complete schedule of all fuses in the panel shall be affixed in a convenient position in the panel, control heater and pilot lamp circuits shall each be protected by a separate fuse. All fuse carriers shall be fully insulated and shrouded type, withdrawable units the design of which shall prevent contact with "live" parts while the fuse carrier is being, or has been withdrawn. Fuse holders and bases shall be manufactured as moulded plastic. Ceramic material will not be accepted. Neutral links shall not be arranged in fuse holders but shall be separately bolted copper links with one link per fuse circuit.

Fuses and links in the same circuit shall be mounted fuse above link in separate rows and not alternate in the same row.

Where incorporated in distribution boards fuse fittings shall have basic sizes of 16, 32, 63, 100 and 200 amp. and holders shall accept fuse links of that rating or any other down to the next basic size.

H.R.C. fuses where used in distribution and light circuits should have a fusing factor of 15 giving "close" protection as defined in I.E.E. regulations.

402.5.2 Distribution Fuseboards

Fuseboard cases shall be of rust proofed, zinc sprayed, heavy gauge sheet steel, having a flush fronted door with concealed hinges and a resilient sealing gasket, providing enclosure protection to at least IP55 unless otherwise specified.

The interior shall be assembled from all-insulated shrouded fuse carriers and bases of the 380V pattern, fitted with phase dividing barriers and all live parts being fully shrouded, all in accordance with BS 5486 or equivalent.

Circuit identification charts shall be fitted to the inside of all fuseboard doors.

All fuse carriers shall be fitted with fuse-links rated to suit the circuit duty. Spare ways shall have fuse links of the same current rating as the carrier, unless different current ratings are called for under the Particular Specifications. The Contractor shall however confirm fuse ratings with the Engineer before fitting fuses to the carriers. Fuse-links shall be of the HRC cartridge type to BS 88, Class Q1, having screw fixings to the carriers

402.6 MOTOR STARTERS

402.6.1 General

Starters shall be housed in damp and dust proof cubicles.

Each starter shall contain all the necessary equipment to control the circuit load and isolate it from the supply in the event of a fault and shall be equipped to comply with the following general requirements unless otherwise specified under the relevant starter duties.

For starting LV Motors direct on line, the starter shall be rated for intermittent duty class 0.3 (up to 30 operating cycles/hour) and utilisation category AC-3 in accordance with BS EN 60947, or as otherwise specified.

The starter cubicles are required to form part of a motor control centre and as such circuit connections, protection devices, etc., shall comply with BS.5486. The starters shall comply with BS.4941 (Motor starters for voltages up to and including 1000 V. A.C.). The motor starter shall be of a rating to carry the full load current of its rated duty at its most severe load conditions. All starters shall be capable of carrying out at least the number of starts per hour at 100 per cent full load torque as detailed in the appropriate clause.

Motor starter control circuitry shall be generally arranged to suit the motor drive and to comply with the relevant clauses in this specification.

Unless otherwise specified, 3-phase, 380V motors shall be provided with Direct-ON-Line starters up to and including 5 kw rating.

For any form the Contractor shall ensure adequate rating for operating under the relevant climatic conditions.

Heat dissipation shall be considered when designing Air Conditioning Plants where relevant.

The tenderer shall also ensure that the equipment he offers can be within the building as designed and that adequate space for service, maintenance and access is retained.

The motor starter shall be of sufficient rating to carry the full load current of its rated duty at its most severe load conditions. Panel control circuits shall operate at 110/220 Vac single phase.

402.6.2 Isolation

Each unit shall be housed in a separate compartment or enclosure and be completely isolated by means of an isolating switch interlocked with the door or cover to allow access only when the switch is open. The isolating switch shall be operated by means of an external handle and shall have provision for padlocking in the "OFF" position. When in the "ON" position, interlocks shall prevent the unit door being opened. Any components still live after this switch has been opened shall be adequately shrouded and have warning labels attached thereto.

The switch shall be capable of carrying continuously the full rated current of the conductor and shall be rated for making and breaking stalled motor current duty as specified in BS 5419. Off-load isolators shall be suitably interlocked to ensure that they do not make or break load currents and be provided with locking facilities in the "ON" position.

Additional physical isolation by means of withdrawable units for ease of maintenance may be offered but is not a Particular Specification. For such an arrangement the live poles shall be automatically shuttered when the unit is withdrawn and the shutters shall have provision for padlocking in the closed position.

402.6.3 Contactors

Power contactors shall be to BS 5424 (IEC 158-1, 947-4) and shall have the following characteristics:

- Rated insulation voltage: ≥ 1000 V
- Rated Operational Voltage : 1000 V
- Rated breaking capacity : 10 times the rated current.
- Electrical life at rated current and 380V
  ≥ 1 million cycles up to 400A utilization category AC3
  ≥ 600 Kcycles above 400A utilization category AC3.

All contactors shall be of the air-break electromagnetically held-on type. All contact pieces shall be readily replaceable and the necessary auxiliary contacts for control, indication and alarm shall be mounted in accessible positions and arranged in the same sequence on each contactor.

402.6.4 Protection

Each starter shall be provided with an adjustable motor over-load and single phase protection device suitable for the motor load and have adjustable trip and reset delays provided, together with manual local and remote resetting facilities. Ambient temperature compensation shall be provided where relevant. Other protection features shall be as specified relevant to the particular drive.

Protection devices shall be arranged to trip the load and initiate the fault indications specified and accept normal switching of load.

Where starters are fed directly from busbars or other systems having a high prospective fault level, suitably rated fuses or other means shall be provided within the starter to limit the fault let through to a value within the rating of the starter components. Protective overload devices shall be arranged to ensure that any such fault is cleared by such fuses and provide Type `2' coordinated protection to BS EN 60947.

402.6.5 Control Circuit

All control circuits shall operate at not more than 110V and be derived from a double wound, screen earthed isolation transformer with one side of the secondary winding connected to neutral/earth. The primary supply shall normally be from one phase to neutral if available.

Individual transformers shall be provided for each starter but sequenced groups of starters having a common isolator shall use a common control transformer.

Fuses shall be provided on each primary and secondary supply and be clearly labelled and segregated. A link shall be fitted in the neutral/earth connection.

The control circuit and the main supply must be isolated before opening the cubicle door but provision shall be made to re-energise the control circuit when the main supply to the cubicle is isolated, so that the operation of the control gear may be inspected without energising the motor. The necessary control circuit Normal/Test switch shall be mounted within the cubicle and so arranged that it is not possible to close the door with this switch in the `Test' position.

The motors in some applications will be required to operate in a predetermined sequence and starters should include suitable auxiliary relays and contacts.

Each plant control panel shall contain a multiple cam contact timer housed in a separate clearly labelled compartment. The timer shall have sufficient contacts to provide as minimum one per starter plus 25 percent spare.

The timer shall allow drives to restart in a predetermined staggered sequence under both automatic and manual (hand) control following a failure of power supply and its restoration.

Each contact shall be fully adjustable between 0 and 30 minutes.

402.6.6 Control and Monitoring

The method of control and operation shall be as called for under the Particular Specifications for the starter.

Control selector switches fitted to the front of starters shall have matching operating handles which are clearly shaped to show the selected position. Specified function switches shall have a key operated barrel locking device in the handle, or be key operated alone, with the key removable in each lockable position.

All fault conditions relevant to each mode of operation shall stop the drive and prevent it re-starting until the particular fault is cleared and individually reset; lock-out relays and a reset button being provided for any self-resetting devices such as excess torque switches etc.

Specified fault conditions shall be identified by separate indications on the starter. Volt-free contacts shall be provided and wired to terminals in each starter unit for remote signalling of all status indications specified. Minimum status indications shall be Auto Available/Un-available and Running/Fault.

Where the starter is to be remotely controlled by a remote terminal unit (RTU), interposing relays with 24 volt DC coils complete with back EMF suppression diodes shall be provided in each starter unit to facilitate remote control and watchdog capability (See Instrumentation Specification).

"Hours-run" meters shall be of the non-resettable cyclometer type indicator having a flush fascia and driven by a synchronous motor connected to show the hours (up to 99,999.9) run by the main motor. They shall incorporate visible indication of operation but need not necessarily be of the same bezel size as the instruments.

All starters for motors of 3 kW and above shall have ammeters, local 'running' indicator lamps being provided for loads less than 3 kW.

402.6.7 Heaters

Anti-condensation heaters shall be fitted in each starter (and motor, where specified), fed from a separate fuse through the starter isolating switch and an auxiliary contact on the motor contactor, arranged so that the heaters are disconnected when the motor is running.

In multi-tiered starter panels, the heater shall be located at low level within each tier and fed from a clearly identified common distribution supply with local isolating links in each tier.

402.6.8 Star Delta Starters

Star/Delta starters shall be of the closed transition "Wauchope" type, having starting resistors, mechanically and electrically interlocked Star and Delta contactors plus a timing relay in addition to DOL starter requirements, all rated for up to 10 starts per hour.

402.6.9 Auto-Transformer Starters

Auto transformer starters shall be of the closed transition “Korndorffer” type, having suitably rated mechanically and electrically interlocked "start" and "run" contactors plus a timing relay in addition to DOL starter requirements.

The auto transformer shall be oversized, Class H, air cooled with tappings provided at 50%, 65% and 80% of line voltage and unless otherwise specified, be suitably rated for up to 10 starts per hour. The transformer shall be contained within the starter panel or may be installed in a separate enclosure.

Contactors of one Starter shall be of the same type and rating. The current rating of the contactors shall be 10% higher than required by the driving motor at continuous maximum rating in utilisation category AC3.

402.6.10 Stator/Rotor Starters

Where separate stator and rotor cubicles are provided, a key interlock shall be fitted to prevent access to the rotor cubicle unless the stator isolating switch is in the `Open' or `Earth' position.

Rotor resistances shall have suitable interlocking facilities to prevent operation of the starter switch until all sections of rotor resistance are in the starting condition.

The resistor enclosure shall be ventilated to IP41 and a thermostat shall be incorporated to trip the starter if the resistance overheats due to excessive use or mal-operation.

Rotor resistances may be metal or liquid material as specified to suit the drive characteristics. Metal resistors shall consist of rustless unbreakable resistor grids which may be readily replaced. Where tiered banks of resistors are provided, it must be possible to readily remove from the front any section without disturbing any other section of the resistance bank.

Liquid or derived vapour resistors shall have the electrolyte contained in leakproof containers and incorporate means of restricting evaporation and detecting loss of electrolyte.

402.6.11 Electronic Assisted Starting

Starters for specified squirrel-cage induction motors shall incorporate a solid state device designed to provide a smooth acceleration up to the motor's rated speed.

The acceleration time shall be adjustable by means of control settings provided to enable optimum maximum starting current and torque as well as initial threshold starting current and torque to be selected.

The starting current of the largest motor shall be limited as specified.

Where specified to reduce system shocks, provision shall also be made for motor stopping under controlled deceleration.

a) <u>Protection</u>

The electronic power device shall be protected by high speed semi-conductor fuses and heat sink thermal cut-outs.

The device shall shut down in the event of single phase loss or open circuited the electronic power device.

In the event of short circuited the electronic power device, the drive shall continue to run at full voltage by automatically transferring to an override condition.

b) <u>Indications</u>

Alarm indications shall be provided for each of the above faults.

An auxiliary relay shall be used to control the function of the main contactor.

c) <u>Energy Saving Facility</u>

For continuous running drives, an energy saving control shall be provided where the voltage applied to the motor is automatically matched to the actual power demand. The control shall be effective after run-up and a dwell time at full voltage has been allowed to enable the motor load to stabilise.

The device shall respond immediately to any sudden load changes to prevent a potential stall condition.

402.6.12 Frequency Converters

The motor speed control shall be a frequency converter of an approved type and manufacture, providing a variable frequency output of adequate capacity to drive the specified motor over the specified speed range and suitably matched to the starting torque and the speed torque characteristics of the driven plant. (Details to be determined by the Contractor from the driven plant/motor manufacturer during the Contract.)

The converter unit with the associated control electronics shall be housed in a steel, free standing, drip protected (IP21) panel, mounted in the position specified. The unit shall be suitably air-cooled by means of an integral fan and all the components within the unit shall be readily accessible for easy servicing and removal without disturbing other components. Chassis units shall be suitable for rack mounting.

The incoming supply shall be via an isolator interlocked with the panel door and have suitable fuse protection.
The drive unit shall be capable of operating with the motor disconnected for test purposes.

A current limiting circuit shall be incorporated to give short circuit and overcurrent protection in the output circuit, and undervoltage detection shall be incorporated to protect the drive against fan failure. A thermostat shall be fitted for protection against fan failure and overheating.

a) Harmonics

The unit shall be protected from any harmonic distortion or switching surges in the power supply system and incorporate contactors to automatically isolate the input and output and to protect the unit from component damage arising from a power supply interruption which shall, if necessary, include automatic shutdown. If the converter will not perform correctly when running from a specified Standby generator an interlock shall be provided to prevent such operation.

To prevent distortion of the supply system wave form (and dependent instrumentation), harmonic voltage and current distortion introduced into the mains supply by the drive unit shall be within the limits specified in Electricity Council Engineering Recommendation G5/3. The point of common coupling shall be regarded as the output connections of the first upstream transformer.

The supplier shall list with the offer the expected harmonics generated by the drive under running conditions (worst case).

Where an input filter is used to limit the harmonic currents, the design shall minimise the possibility of resonance with any power factor correction capacitors fitted.

The supplier shall include any shielding necessary in accordance with BS 800, to prevent any interference that may affect other surrounding instruments.

b) Monitoring and Control

The control of each variable drive unit shall normally be from a PLC outstation which will provide a start/stop facility and a 4-20mA speed control signal. Where the distance between the drive unit and PLC exceeds 20m, special care shall be taken to ensure radio frequency interference and distortion are kept to a minimum.

The following signals will be required from the drive unit and wired to clearly marked terminals:

(a) Common fault (motor overload, emergency stop operated etc)
(b) Control status indicating Hand/Off/Auto
(c) Control 'on'
(d) Motor available
(e) Motor running
(f) RS 232 Serial Interface (where required by the specification).

The following items shall be included along with other control devices and instrumentation:

a - Control potentiometer for speed setting on hand control, (scaled with linear graduations over the range and arrows indicating clockwise rotation to `INCREASE SPEED' and anti-clockwise rotation to `DECREASE SPEED');
b - Output ammeter;
c - Frequency/speed meter;
d - Test and fault diagnostic card for circuit checking, having a front of panel display and facility for serial link remote indication.
e - Isolated inputs for 0-10/4-20mA auto control, start/stop, external reset, etc.
f - Adjustments for ramp up/down, duration, frequency range, base/maximum speed, current limiting facility and economy mode.

The following items shall be monitored for fault conditions:

- Phase failure
- Earth fault
- Overcurrent
- Over voltage
- High temperature/fan failure
- DC link fuse failure

402.7 ELECTRIC ACTUATORS

402.7.1 General

Electric actuators shall be suitable for outside installation and all components shall be housed in waterproof enclosures to IP67 or better, which shall incorporate an anti-condensation heater. Actuators shall be designed in such a way, that exposure to environment will not interfere with the safe operation. All joints shall be sealed by radial seals or O-rings. In order to prevent loss of screws, all covers which can be opened for setting and service shall be fixed with captive screws.

The whole actuator shall be of easily maintained design. Electrical connection shall be by means of plug and socket to enable easy and quick disconnection during commissioning and maintenance works. The actuators shall be of robust construction. The design must provide simple setting, testing, maintenance and repair. Torque and limit switching shall be of the mechanical type to allow settings without special tools or instruments (e.g. battery backed setting tools). Actuator shall be sized to guarantee the penstock or valve opening or closing at the maximum differential pressure specified herein. The operating speed shall be approximately 300mm/minute unless otherwise specified.

All actuator component items shall be coupled via flanged mating faces secured by stainless steel bolts, except valve mounting fixings subject to thrust forces which shall be by means of suitably sized, high tensile steel bolts.

The gearbox shall be of the worm gear totally enclosed, with lubricant, having a cast iron housing suitable for operating at any angle and provided with the appropriate filling and drain plugs. Housings made out of aluminium shall not be allowed. The actuator drive bushing shall be easily detachable for machining to suit the valve stem or gearbox input shaft and the length of the drive nut shall not be less than 1.25 x the spindle diameter.

In case quarter-turn-gearboxes are required in combination with multi-turn actuators to operate the valve, the gear housing shall be made out of cast iron (GG) or ductile iron (GGG). End stops in both directions, located at the input shaft (not the gear housing) shall be available by means of a travelling nut to protect the valve against excessive torque. The gearbox shall be designed as per valve and actuator requirements. The worm wheel shall be made out of bronze. Segment type worm wheels or spindle type shall not be used. Enclosure for gearbox shall be IP67.

The output shaft shall be hollow to accept a rising spindle where appropriate, and incorporate thrust bearings of the ball or roller type. The design shall preferably permit the gear case to be opened for inspection without releasing the spindle thrust or taking the penstock/valve out of service.

402.7.2 Motors

All motors fitted to actuators shall be specially designed for the application and of the squirrel cage induction type for operation from the single phase Power supply system of 220 Vac ± 5%, 50 Hz.

All motors shall be specifically designed for valve-actuator operation which is characterized by high starting torque, low stall torque and low inertia.

Motors shall be of the non ventilated totally enclosed type (TENV).

Motors must be totally separated from the lubricant-filled gearing of the actuator, allowing to replace a motor without loosing any lubricant regardless of mounting position.

Motor-insulation must be in accordance with IEC 85 Class F (155^{o} C).

The rated output of the motors shall be determined by the tenderer in relation to the requirements of the mechanical plant described elsewhere in this specification, and starting torque shall be at least 10% in excess of maximum service requirements. The intermittent running load factor shall be 25% in accordance with VDE 530.

The motors shall preferably be 4 pole 1440 revs/minute machines designed with adequate thermal capacity to ensure that the actuator and starter can adequately perform, without overheating, the number of successive opening and closing operations, in no case shall this number be less than three.

Each motor shall be fitted with a thermostat or thermistor per phase arranged to stop the motor in the event of dangerously high temperature in the motor windings due to overcurrent or an abnormally high number of starts per hour.

402.7.3 Manual Operation Interlock

The actuator shall have a side mounted handwheel for manual operation which will be at standstill during motor operation. A lever shall be provided for engaging the handwheel drive, and this shall be interlocked so that when starting the motor the handwheel is automatically uncoupled without danger to the operator. Provision shall be made for the lever to be padlocked in either position to prevent hand or motor operation as required.

Clockwise operation of the handwheel shall cause the valve to close. The face of the handwheel shall be clearly marked with an arrow and the word ‘CLOSE’.

The handwheel must be sized in such a way, that one man can generate the rated actuator output-torque. The torque switches shall be active in manual operation mode as well, thus allowing to provide a signal when the set-torque has been reached.

Under manual operation, the handwheel shall drive the worm shaft. Self locking shall be maintained in hand operation. The motor must be disengaged during manual operation. The handwheel shall automatically disengage when the electric motor is energised.

402.7.4 Position Monitoring

A mechanical position indicator, showing the open, closed or intermediate positions of the valve on a visible dial, shall be incorporated in the actuator housing. Alternatively, where specified, a continuous position indicator shall be provided.

Remote position indicators, where specified, shall be controlled from a suitable potentiometric drive arranged to provide a continuous proportional signal from `Open' to `Closed' positions.

402.7.5 Position Control

Where specified for control purposes, a current position transmitter shall be provided to give a positive 4-20mA signal proportional to the valve position, and shall incorporate zero and span adjustments to suit the actual valve travel.

402.7.6 Torque and Limit Switches

All switches shall be accommodated within the actuator housing and all contacts and mechanism shall be of sealed, rustproof and robust construction. All switches (limit and toque) shall be of the snap-action micro switch type, totally enclosed acc. IP66, each with one set of NO contacts and one set of NC contacts. The connecting wires shall be sealed in the switch-housing. Torque switch signalisation must be active in manual operation (by handwheel) as well. Adjustable torque limiting devices and switches shall be provided to trip the starter in the event of mechanism overload due to obstructions or jamming etc. Limit and torque switches must be operated by counter gear-driven cams, which are mechanically linked to the driving devices, without slip-clutches. No battery backed limit sensing shall be used to avoid malfunction of the actuator in case of power failure or dead battery.

Adjustable limit switches shall be arranged to trip the starters when the `fully open' or `fully closed' positions are reached. Should the manufacturer consider it desirable (to ensure proper seating) the travel may be stopped in the `fully closed' position by the torque limit switches, but in this case the `fully closed' limit switches shall still be provided, although they will be adjusted to be inoperative.

The actuator shall be equipped with two independent torque limit switches operating in both rotational directions.

402.7.7 Auxiliary Switches

Two adjustable auxiliary switches shall be provided. They may be used for remote controls or indications monitoring the `Open' and `Closed' positions.

402.7.8 Terminal Facilities

All electrical components shall be wired out to a plug/ socket connector, to allow quick disconnection in case of maintenance or repair in a common terminal plug incorporated in the actuator housing.

Each terminal shall be labelled to correspond with the diagram of connections and shall be capable of accommodating not less than 2.5mm^2 copper conductors.

Terminal blocks shall comprise shrouded anti-tracking mouldings of melamine phenolic or comparable material with provision for securing conductors by screw connector or other approved vibration-proof devices.

The terminal compartment shall provide sufficient space to accommodate the possible maximum number of incoming wires. Separate cable entries (2XPG21, 1XPG13,5) must be provided for motor power cables and controls, [*]connection for redundant bus cabling and the required final resistors for bus termination.

[*]For two wire communication only

Each cable entry shall be properly sealed by cable glands during site installation. The cable glands size shall be chosen by contractor responsible for wiring during commissioning phase.

Any conduit entries not used after cabling is completed shall be plugged with threaded aluminium blanks and the threaded joints made watertight by using suitable tape or jointing compound.

402.7.9 Starters and Control Gear

The actuator motor shall be controlled through integrally mounted electrically and mechanically interlocked contactors, rated for switching the motor direct on-line, adequate for the duty requirements and complete with all necessary auxiliary contacts for the functions specified herein.

The control circuit shall operate at 24V DC derived from a suitably rated transformer/rectifier with one side of the secondary winding connected to earth or as otherwise specified. Primary and secondary windings shall be protected by cartridge type fuses.

The method of control and operation shall be one of the following options as called for in the Particular Specifications and the actuator shall be provided with any facilities called for therein to suit the method of control, whether this be automatic or by hand. Local controls integrally mounted on the actuator shall consist of push buttons for `Open', `Close' and `Stop' functions, together with a Remote/Off/Local selector, lockable in all positions. The "Emergency Stop" button shall be effective in both local and remote settings and operate directly in the contactor control circuit.

Option A) Standard controls and signalisation

The following features shall be in the integral motor controls:

- Reversing contactors (mechanically and electrically interlocked). An electronic reversing unit (thyristor) shall be available as an option up to 1,5kW.
- Programmable control logic in CMOS SMD-technique

Remote Commands

- Remote commands ‘OPEN - STOP - CLOSE’, potential separation by opto-isolators
- Control voltage for remote commands, 24V DC, internally or externally supplied.

Output Signals

- Signal from selector switch, position ‘LOCAL - REMOTE’, with potential-free contacts
- Signals for end positions ‘OPEN - CLOSED’ with potential-free contacts
- Monitor relay for collective fault signal (power failure, phase failure, wrong phase sequence, thermoswitch tripped and torque switch tripped in mid travel)
- Control voltage 24V DC, externally supplied.

Option B) Communication via bus system

The following features shall be in the integral motor controls:

- Reversing contactors (mechanically and electrically interlocked). An electronic reversing unit (thyristor) shall be available as an option up to 1,5kW
- Programmable control logic in CMOS SMD-technique
- An interface board for digital two wire control communication shall be available, preferably supporting the PROFIBUS FMS protocol according to EN 50 170. The protocol shall be based on the ISO / OSI layer model (ISO 7498, 1994). FMS communication according to DIN 19245 parts 1 and 2. Physical interface RS 485.
- It shall be possible to have direct communication between actuators and higher level DCS systems, without using additional master stations as protocol translators.

The two wire communication shall include:

- Multimaster function: the actuator shall be able to communicate with several masters
- Master redundancy: the actuator shall be able to support several designs of master redundancy
- Slave initiative: the actuator shall be able to generate messages for the master which results in shorter reaction times
- Data transmission speed shall be 9,6 kbit/sec. To 187,5 kbit/sec.

Commands:

- Run OPEN / run CLOSE / STOP
- Run to an intermediate position
- Perform alarm operation

Signals:
- Ready for service (OK)
- Valve positions OPEN / CLOSED
- Actuator in pre defined intermediate position (option)
- Mode of operation - position of selector switch OFF / LOCAL / REMOTE
- Fault Signal, including:
- ♦ Phase sequence and phase failure
- ♦ thermoswitch tripped
- ♦ torque switch in 'OPEN' direction tripped in mid travel
- ♦ torque switch in 'CLOSE' direction tripped in mid travel
- Status:
- ♦ actuator stands still
- ♦ actuator runs
- ♦ actuator performs an operation after an adjustable delay time
- ♦ actuator performs an emergency operation
- ♦ actuator stands still, alarm status active

The following options shall be made available:

- Positioner:

A positioner can be provided within the equipment. The nominal position value shall be sent as reference input from an external controller to the actuator. The integral positioner generates the signal for the motor controls, depending on the difference between input command signal and position feedback signal. Position feedback is provided within the actuator.

- Analogue sensor connection:

The actuator shall be additionally equipped with an interface enabling the connection of an external analogue sensor (0/4 to 20mA).

- A digital input signals:

The actuator shall be additionally equipped with four digital input signals.

- Repeaters:

The actuator supplier shall also provide repeaters if required by plant set-up.

Wherever motorised penstocks and valves are specified, they shall be provided with adequately rated starters. The starters shall be electrically attached to the actuator via a plug and socket connection to the actuator in a robust constructed housing and shall form a totally enclosed weatherproof unit with the actuator. The design shall allow to alter the position of the local controls at site (without special tools) in such a way, that the switch lever and push-buttons face the operator. Depending on the application, it shall be possible to separate the actuator from the local controls and to install the local controls (including motor controls) at a pillar or for mounting at a wall. A wall bracket shall be available as an option. The IP67 enclosure shall not be effected from this. The motor starter shall be capable of starting the motor under the most severe conditions.

The starter housing shall be fitted with contacts and terminals for power supply, remote control and positional indication, and shall also be fitted with internal heaters to provide protection against damage due to condensation. Heaters shall be suitable for single phase operation. The heaters shall be switched to "ON" when the starters are "OFF" and shall be switched "OFF" when the starters are "ON".

402.7.10 Painting and Corrosion Protection

Corrosion protection shall fulfill the requirements of salt spray tests in accordance with DIN 50021.

Actuator painting must be performed in such a way, that no corrosion takes place under the ambient conditions as specified. All outside screws or bolts shall be made out of stainless steel (A2).

Surface preparation for cast iron parts shall be sand blasted, equivalent to Sa 2½ according to SIS 0559 000-1967 / DIN 55 928, part 4. Surface treatment for external parts which need to be removed during commissioning or maintenance shall be electro dip coated or metallic surface protected. Primer coating shall be a 2-component primer based on epoxy resin with micaceous iron oxide. Finish coating shall be a 2-component coating based on polyurethane micaceous iron oxide. Colour shall be silver grey (DB 701), similar to RAL 9007). Entire film thickness shall be app. 140 μm.

402.7.11 Name Plates

Two nameplates, made out of stainless steel, shall be attached to each actuator; one on the motor housing, showing all relevant motor data, one on the actuator housing showing all relevant actuator data. Special information, like the valve tag no., shall be shown if required.

The nameplates shall be securely fixed to the actuator and motor, so that they cannot be removed or scratched off during shipment, installation, operation or maintenance.

402.7.12 Actuator Isolators

Unless otherwise specified, motorised actuators shall have an isolator switch. The switch shall have a slow make and break mechanism of the two position rotary pattern arranged to isolate the 3 phase supply and all other control circuit supplies to the actuator. The isolator rating shall be based on the actuator average load current being switched normally off-load, but emergency on-load.

Each switch shall be incorporated in a heavy duty, hoseproof, cast aluminium enclosure to IP65, having external fixing lugs and adequate seals and drip shields on the operating shaft and cover. Austinlite rotary type EXO 190 or equal.

Switch positions shall be 90° apart, clearly and permanently inscribed or embossed as `OFF' and `ON' on the cover, and the switch handle shall incorporate provision for the switch to be padlocked in both the `OFF' and `ON' position. The `OFF' position to be to the left of centre or vertical, the `ON' position to the right or horizontal.

It shall be possible to remove the switch cover for access to the terminal without disturbing the switch or its mounting base. The enclosure shall be suitable for mounting on, or adjacent to, the penstock pedestal. If mounted on the penstock pedestal, cabling between the isolator and the actuator above may be arranged through conduit connections, suitable for disconnection should it be necessary to remove the actuator assembly complete.

(This item preferably to be provided by the contractor who is responsible for the cabling.)

402.8 ROTATING ELECTRIC MACHINERY

402.8.1 General

Machine type and starting or driving arrangements together with type of enclosure protection shall be as specified herein. Vertically mounted machines shall be fitted with a drip-proof top end cowl and those fitted with skirts shall have a skirt depth in excess of the shaft extension.

Each machine shall comply with the current BS 4999 and the relevant parts of BS 5000 and shall be designed to run at a high power factor and efficiency at the prescribed plant duty.

402.8.2 Rating

The output of each machine shall be a continuous maximum rating (Duty type S1) determined by the Tenderer in relation to the power requirements and the normal working environmental conditions for the plant offered in accordance with this Specification. The maximum temperature rise of any machine winding shall not exceed 80°C above a 40°C ambient when operating at the above rating. Where the insulation is rated up to 120°C only, the maximum plant loading shall not exceed 95% of the rated output of the machine.

402.8.3 Electric Motors

Motors shall be suitable for operation from a standard supply voltage of 380 Vac ± 5%, 50 Hz, 3 phase having the star point earthed and the phase sequence running R-Y-B anticlockwise. Motors rated less than 0.5kW may be arranged for single phase operation.

The direct starting current (I_S) of electric motors shall not exceed 7 times the nominal rated current (I_N). The rotational speed shall not exceed 3000 rpm unless otherwise specified in PS.

The torque available during starting of each motor shall be at least 20% in excess of the maximum required at any speed to satisfactorily start and accelerate the mechanical plant load under all service conditions.

All motors shall be of the asynchronous squirrel cage induction type, single or multi cage versions. Other types will not be considered unless the tenderer can show at the time of submitting his tender that such motors cannot be obtained from any source or that in view of size the starting current is prohibitive in terms of either plant compatibility or loading acceptability. In the event of starting current being the problem the tenderer must put forward alternative offers, the first and main offer using squirrel cage motors of either type and the second using alternative motors.

The alternative will not be considered without the main offer.

All motors shall be suitable for operation within the specified environment, and consideration shall be given to the effects of the corrosive atmosphere. Motors for exhaust fans of dangerous fume, gas or explosive atmosphere shall be only of 3 phase type.

All motors intended for outdoor and indoor use shall meet or exceed the requirements of IP55 with regard to protecting from harmful ingress of sand and dust and harmful effects of water projected from a nozzle.

All motors shall be suitable for operation in the climatic conditions detailed in the Specification and in ambient temperature up to 40°C.

The site rating, if derating applies, and normal ratings of all motors together with all performance data be provided with the offer.

All outdoor motors shall be provided with suitable covers to protect them from direct sunlight. Motor cowls shall not be fabricated in fibreglass or plastic.

The efficiency and power factor of the motors shall be high over a wide range of load conditions and the motors shall be designed, manufactured and tested in accordance with BS.4999 and BS.5000 or BS.2048 and BS.5000 in the case of small power motors up to and including 0.75 kW in rating.

For insulation class of electric motors, refer to Particular Specification.

A winding connection diagram shall be supplied permanently affixed to the inside of the terminal box or cover for classification of windings insulation and classification of temperature rise limitation (refer to PS)

Motors shall be of a duty type to suite the driven machine and suitable for the minimum number of starts per hour stated in PS.

The continuous maximum rating (C.M.R.) of each motor shall be in accordance with the following requirements : -

Application	Up to 75 kW Drives	Above 75 kW Drives
All pump motors (excluding positive displacement type)	10% above the calculated maximum power requirements under all conditions of operation	5% above the calculated maximum power requirements under all conditions of operation
Positive displacement pumps & accessories	25% above the calculated power requirements for normal duty or 5% above the power required for maximum duty whichever is the greater	12 1/2% above the calculated requirements for normal duty or 5% above the power required for maximum duty whichever is the greater.
All other drives, including screens, tank scrapers, etc and process plant.	50% above normal duty requirements	25% above normal duty requirements.

The above percentages shall be added to the calculated power requirements for motors, prior to making the necessary adjustments (increased ratings) for high ambient temperature at site. A higher percentage shall be added to the calculated power requirements for motors, if specified in the appropriate machinery section of the specification.

All motors shall be capable of developing a minimum starting torque of 150 per cent of the full load torque. It may, however, be necessary to limit the starting torque on some drives and this shall be achieved by the form of starter and method of starting.

The site rating and normal ratings of all motors together with all performance data shall be provided at the time of tender.

All guaranteed and technical data shall be that for an ambient temperature of 40°C, although all proving tests at the manufacturer's works shall be carried out at ambient temperature. The declared site rating at 50°C shall be estimated by means of approved recognised method and the manufacturer shall provide derating curves for each motor and these shall be included in the maintenance instructions. Where identical type and size motors are being supplied one motor only shall be subjected to full tests and the remaining units to abbreviated tests.

All motors shall have terminal boxes arranged to accept both the main cable and a separate anti-condensation heater cable.

Termination boxes and terminals shall be of suitable dimension to accept appropriate oversized cables to suit site required derating factors.

All motors drivers shall be labelled to correspond with their respective starters.

Arrangements shall be made with the manufacturer so that the Engineer may witness motor tests if so desired Triplicate copies of motor Test certificates shall be provided for approval. Additional copies shall be provided and included in the operating and maintenance instructions.

i) Overspeed and Reverse Rotation

Each motor shall be capable of satisfactory performance during a period of 2 minutes whilst it is run at 1.2 times its rated speed and subsequently at normal speed continuously.

Where specified (to cater for backflow consequent upon delivery valve failure), pump motors shall be capable of reverse rotation up to these speeds without damage.

ii) Electromagnetic Brakes

Where an electromagnetic brake is fitted to a drive, the brake shall be continuously rated. It shall be suitable for direct connection across the associated motor terminals or for individual supply and interlinked control, depending on the method of operation and control specified herein.

The brake shall be arranged to fail-safe by holding on under spring return passage when the coil is de-energised and have provision for hand easing for maintenance purposes. All control circuits for brakes shall be arranged to fail-safe.

Coil and terminals shall be totally enclosed in a fully weatherproof housing.

iii) Water Supply Submersible Pump Motor

Submersible pump motors shall be heavy duty, designed for long running period without maintenance and shall operate at any immersion depth.

Motor frames for submersible pumps liable (even by accident) to submersion shall conform to a degree of protection of not less than IP68.

The pump and its associated motor shall form a compact integral pumping unit suitable for installation within the area specified. The motor shall be of squirrel-cage construction suitable for starting method as called for in the PS, and rated for continuous submerged operation in water having a maximum temperature of 25°C. unless otherwise specified in PS.

The motors shall have a flanged connection at the shaft end in accordance with NEMA Standard.

Unless otherwise specified, the motors shall have an efficiency of at least 80% when operating between 75% and 100% of nominal power output and shall operate at a power factor of at least 0.8 in the same output range.

Motors shall be continuously rated at least 20% above the maximum power absorbed by the pump within the specified operating range. Motors shall be designed to allow a # of starts per hour. (Refer to the PS)

Unless otherwise specified, the motor housing shall be constructed from chromium stainless steel not welded, and shall be designed for easy dismantling and re-assembly to facilitate replacement of motor guide and thrust bearings.

The motor windings shall be insulated with an approved heat resistant material of high insulation resistance and impervious to water. All connections on the motor windings shall be made watertight. The temperature rise of motor windings shall be limited to 45ºC above ambient water temperature. The class of insulation shall be "Y" type and the motor stator shall be rewindable unless otherwise specified.

The motor shall be equipped, in factory with a minimum of three (3) Pt100 thermoprobes for readout, control, signalling, etc...

The motor shaft shall be machined from high tensile chromium stainless steel of sufficient diameter to prevent distortion from the dynamic and electro-magnetic stresses imposed on it. Critical shaft speed shall be well above the maximum running speed.

The motor shall be provided with a heavy duty multi-pad thrust bearing at the base of the motor (MITCHELL Type) to absorb the shaft down thrust developed by the pump. The bearing design shall incorporate tilting thrust pads with replaceable segments arranged to self adjust according to the thrust load. The thrust disc shall be of a suitable segments carbon based or similar approved material. The minimum downward thrust capacity shall be 40 KN.

The thrust bearing design shall also be suitable for reverse rotation of the shaft in the event of backflow of water through the pump.

Motor guide bearings shall utilise either leaded bronze, copper impregnated carbon or similar approved material. Rubber, nylon, Tufnell and similar materials will not be accepted for the motor guide bearings.

Motor guide and thrust bearings shall be lubricated by the motor coolant water, containing non-toxic antifreeze added in the factory and protecting the motor down to -8ºC, which shall be effectively isolated from the water to be pumped. A compensating device shall be incorporated in the motor design to allow for expansion of the coolant when its temperature rises.

Submersible pump motor shall have a mechanical seal with silicon sides and a sand slinger.

A length of butyl rubber insulated, CSP sheathed flexible cable shall be provided and connected to the motor. Unless otherwise specified, the cable length shall be at least 20 metres without joints. The cable cores shall be phase coloured and be suitable for carrying the motor full local current under the specified operating conditions. The cable sealing gland shall be a watertight design and, where included within the pressurised pipework, shall be capable of withstanding a water pressure of 1.5 times the closed valve head generated by the pumping plant.

iv) Motors for submersible pumps for sewage and river water applications

Motors shall be heavy duty, designed for long running period without maintenance and shall be suitable for wet and dry installation unless otherwise specified in the PS.

Motor frames shall conform to a degree of protection not less than IP68.

The motor shall be of squirrel-cage construction suitable for starting method as called for in the PS, and rated for continuous submerged operation in water having a maximum temperature of 40°C unless otherwise specified in PS.

Unless otherwise specified, the motors shall have an efficiency of at least 80% when operating between 75% and 100% of nominal power output and shall operate at a power factor of at least 0.8 in the same output range.

Motors shall be continuously rated at least 20% above the maximum power absorbed by the pump within the specified operating range. Motors shall be designed to allow a # of starts per hour. (Refer to the PS)

Unless otherwise specified, the motor housing shall be constructed from chromium stainless steel not welded, and shall be designed for easy dismantling and re-assembly to facilitate replacement of motor guide and thrust bearings.

The motor windings shall be insulated with an approved heat resistant material of high insulation resistance and impervious to water. They shall be suitable for class S1 duty even when not submerged. All connections on the motor windings shall be made watertight. The temperature rise of motor windings shall be limited to 45ºC above ambient water temperature. The class of insulation shall be “F” type and the motor stator shall be rewindable unless otherwise specified.

The motor shall be equipped, in factory with a minimum of three (3) Pt100 thermoprobes for readout, control, signalling, etc...

The motor shaft shall be machined from high tensile chromium stainless steel of sufficient diameter to prevent distortion from the dynamic and electro-magnetic stresses imposed on it. Critical shaft speed shall be well above the maximum running speed.

The thrust bearing design shall also be suitable for reverse rotation of the shaft in the event of backflow of water through the pump.

Motor guides and bearings shall utilise either leaded bronze, copper impregnated carbon or similar approved material. Rubber, nylon, Tufnell and similar materials will not be accepted for the motor guides and bearings. Motor guides and bearings shall be maintenance free, lubricated for life.

Motor cooling shall be ensured by blockage free jacket cooling system with heat transfer by continuous medium circulation by means of pumped liquid. For motors up to 10 kW, the stator casing shall be equipped with extended surfaces to obtain maximum heat dissipation with the surroundings.

Motors shall have two independent mechanical face seals mounted in tandem with an interposing oil chamber which is used to lubricate the seals and to act as an additional leakage barrier. The seals shall be silicon carbide on the medium side and carbon chrome on the motor side. The oil chamber shall be equipped with a sensor to give a timely indication for regular inspection and shall act as a detector for oil leaks and water in oil. The oil chamber shall be filled with physiologically harmless paraffin oil. The oil shall be free from aromatic hydrocarbons, medically clean and be approved according to FDA 172.878

The stator housing shall be equipped with a humidity sensor installed at the bottom of the housing. This sensor monitors the humidity level in the stator housing.

The supporting bearings shall be equipped with a temperature sensor monitoring the temperature of the bearings.

The motor connection chamber shall be separate , water-pressure tight (at depths up to 20m) encapsulated, with two stage cable inlet with strain relief and anti-kink protection.

402.8.4 Terminal Boxes and Connections

Terminal boxes shall be provided, suitable for PVC/SWA/PVC cables for all external cabling connections.

All boxes shall be bonded to the main frame earth and the frame of each machine shall be provided with means of connecting an earth protective conductor.

Each machine rated 10kW or above shall have the six ends of the stator winding extended to the terminal block with the necessary linking effected there, adequate clearance being provided between phase terminations to permit the use of cable sockets.

For high voltage machines the terminal assembly shall be capable of satisfactorily withstanding the full fault capacity specified herein for 1 second.

402.8.5 Heaters

The motors shall be fitted with anti-condensation heaters of a size to maintain the temperature of the windings 5ºC above ambient. Each heater shall be provided with a switch and also an automatic control, within the respective starters, to disconnect it when its motor is in operation.

Anti-condensation heaters shall be provided in all non-submersible machines as an integral part of the machines and wired with butyl rubber insulated tails to a terminal box adjacent to the main terminal box, the cover being clearly labelled `Heater Supply - 220V'.

Heaters shall be of the embedded element type having a low surface temperature and be impervious to moisture. They shall be arranged to operate on a 220V supply from the associated control unit when the motor winding is de-energised.

402.8.6 Maintenance Facilities

Machines rated over 50kW shall have lifting ears or eyes forming part of the main frame of the machine and both ends of the rotor shaft shall be drilled and tapped for maintenance lifting and pulling facilities with a single tapped hole in accordance with the tables given in BS 4999 (Part 10). Depth of tapped hole shall be 1.5 times the diameter.

402.8.7 Bearings

Bearings shall be of the heavy duty ball or roller type greased for life enclosed in a substantial housing designed so that lubricant cannot escape on to the windings and fitted with adequate seals to prevent contamination or escape of lubricant down the rotor shafts. Means of lubrication shall be made available from outside the machine carcass or enclosure. The shaft shall be suitably located to prevent the rotor from moving out of magnetic centre while starting or running.

The rotor of any vertical spindle machine shall be provided with a suitable thrust bearing to support the weight of the rotor and its half coupling only.

The bearings caps on the non-drive end covers of the motors shall be arranged so as to allow a speed check to be taken.

402.8.8 Slip Rings

All machines which incorporate slip rings shall be so designed that the slip rings and associated slip ring mountings shall form a single unit which can be readily detached from the shaft for repairs and replacements. The slip rings shall be continuously rated and of the totally enclosed type.

402.8.9 Noise Level

The motors shall be commercially silent in operation and run free from vibration. The rotors shall be balanced both statically and dynamically and shall be tested and adjusted, in an approved manner.

402.8.10 Protection of Motors

For motors rated less than 2 KW, a three pole, thermal overloads with single phasing protection, shall be provided.

All motors above 2 KW shall be fitted with three Pt 100 internal thermal devices. They shall be arranged such that in the event of device operation, a lock out function shall operate to prevent automatic re-start upon temperature reduction. The tripped indication shall operate.

For motors rated above 2 KW and up to and including 75 KW shall be protected by three pole adjustable thermal magnetic overloads and single phasing protection.

Motors above 75 KW, unless otherwise specified, should be protected by an electronic protection relay which shall incorporate a thermal equivalent circuit taking into account both the copper and iron losses in the motor, thereby producing characteristic that closely follows the overall temperature of the motor during starting, running and cooling. The unit must follow the cooling characteristic during a loss of supply and must pick up at the correct point on the curve when supply is restored.

The trip characteristic shall be adjustable, so that it can protect motors having differing maximum locked rotor times and currents therefore shall protect motors with long run-up times.

402.8.11 Motor Manager

The device shall be a self monitoring unit with the following operating features : -

- select and change operating parameters.
- select and modify setting values.
- display values and modifications.
- indicate faults.
- test, e.g. verify the unit operation.
- reset: Enable the unit after a trip.

Technical data

- Operating temperature : -5ºC to 60ºC
- Storage temperature: -40ºC to 60ºC
- Climatic sensitivity: as per IEC 68-2-3 and IEC 68-2-30.
- Degree of protection: IP65
- Resistance to vibration: as per IEC 68-2-6.
- Resistance to shock: as per IEC 68-2-27.
- Noise emission and noise proof as per EMC standard.
- Power supply module shall be self-protected against short circuits.
- Data shall be retained in case of voltage supply failure.
- Fail-safe operation.
- Output relays (contacts) galvanically separated.

Protective functions

- Thermal overload.
- Asymmetry.
- Overload.
- Rotor stalling during running and starting period.
- Underload
- Earth fault.
- Long starting (Monitoring of starting time).
- Limited starts per hour.
- short circuit.
- Thermistor (PTC) input.
- Phase sequence.
- Phase failure.
- Pt 100 input (up to six No.)

This unit shall be equipped as well with a communication interface to enable data exchange with logic controllers or PLCs.

402.9 CIRCUIT BREAKERS

402.9.1 Low Voltage Air Break Circuit Breakers

The air break circuit breakers shall be suitable for control loads as for maximum operation, and shall comply with BSEN 60947 for 380V, 3 Phase, 50 Hz. 4-Wire operation for use on 31MVA fault level for 1 second for climatic conditions.

All low voltage circuit breakers shall be housed in control boards which comply with the requirements of Electrical Panels.

The circuit breakers should be horizontally isolated, horizontal draw-out pattern, air break type. The closing and tripping mechanism shall be in accordance with manufacturer's recommendation. The circuit breaker closing mechanism shall be a HAND spring charging or solenoid type.

The operating mechanisms shall have a mechanical ON/OFF indicator and a manual trip device fitted with means for locking, test terminal blocks, healthy trip lamp (coloured white) and associated push buttons, set of auxiliary switches, supply available lamps (on incoming units only) cable boxes complete with glands of suitable size for the accommodation of the incoming and outgoing cables entering from below.

Closing solenoids shall be suitable for operation at 80 per cent of the nominal solenoid supply voltage.

Closing and tripping batteries shall comply with the Safety Interlocks requirements.

Auxiliary contacts for the indication of breaker state for use at 30V. D.C. shall be provided.

Slow closing of the circuit breakers to facilitate maintenance and contact adjustment shall be provided. This operation shall be possible only with a circuit breaker in the fully withdrawn position. Any necessary handle or lever shall be included in the schedule of spare parts.

Individual shutters which automatically operate as the truck is racked in and out, shall be provided for busbar and circuit spouts. When closed the shutters shall effectively prevent any contact with either the busbar or the circuit connections and also seal the spouts against the ingress of dust. The shutters are to be coloured and painted in bold characters with "BUSBARS" (red) or "CIRCUIT" (yellow) as appropriate in Arabic and English. Provision shall be made to lock each shutter in the closed position.

Facilities shall be provided for testing the circuit breaker operation when in the isolated and withdrawn positions.

There shall be a purpose designed, separate earthing device. The device shall be arranged to earth either the cable box or the busbar side of the circuit breaker, and shall be stored in a suitable robust container which shall include a permanently fixed instruction label in Arabic and English giving details of assembly and use.

Auxiliary jumper connection, as necessary, shall be included.

The height of any controls shall not exceed 1800 mm, above finish floor level.
All circuit breakers shall be provided with interlocks to ensure that : -

i- Circuit breaker cannot be plugged in or isolated when it closed.

ii- The circuit breaker cannot be closed until it is fully plugged in or completely isolated.

iii- The circuit breaker cannot be closed in the service position without completing the auxiliary circuits between the fixed and moving position.

iv- The circuit breaker cannot be slow closed except in the fully withdrawn position.

v- The circuit breaker can only be operated manually in the withdrawn position.

The incoming circuit breakers shall be fitted with a voltmeter (0-600V) with selector switch to read voltage of the line to line and line neutral.

Ammeters shall be fitted on the busbar side, voltmeters on the line side of the incoming circuit breakers.

To facilitate the removal of circuit breakers for maintenance, there shall be supplied if necessary, a purpose designed hand operated trolley.

402.9.2 Moulded Case Circuit Breakers

Moulded case circuit breakers shall be of the quick make, quick break, trip-free type complying with BSEN 60947 and shall be complete with the following:

402.9.2.1 Type "A" circuit breakers

With an Electronic Trip Unit for protection as follows:

Long time protection against overload with adjustable threshold:
Ir = 0,4 to 1*In and adjustable time delay.
Short time protection against short-circuits with adjustable threshold:
Im = 2 to 10 In and adjustable time delay: 0.05 s to 0,30 s.
Instantaneous protection against short circuit with adjustable threshold:
I = 1,5 to 11 In
Earth fault protection with adjustable residual current threshold:
0.2 to 1xIr and time delay threshold: 0,2 s to 0,40 s.

- A minimum of 4 Auxiliary changeover switches that indicate pole position and a minimum of one auxiliary switch for tripping.

- A shunt trip release for remote tripping.

- A motor mechanism for remote control closing with the following main characteristics and auxiliaries:
  a) Remote spring charging after an opening by a shunt trip release.
  b) Toggle extension for manual spring charging.

- Terminal shields and Phase barriers.

- A counter that indicates normal Open/Close or tripping of the circuit breaker shall be installed for maintenance operation.

- One calibration test kit shall be supplied with connecting cables used to check the operation of the trip units of all circuit breakers.
-
- Visual indication of Open, Close and Trip conditions shall be provided. Circuit breakers shall be padlockable in the “OFF” position.

N.B. All circuit breakers shall normally operate at no-load.

402.9.2.2 Type “B” circuit breakers:

- All characteristics of type “A” circuit breakers.

- Each circuit breaker shall be mounted on a withdrawable chassis with the following functions:

  a) Operations on disconnected position: the power circuits are disconnected, the circuit breaker is simply “withdrawn” and may still be operated and controlled (on, off, push-to-trip etc...)

  b) A safety trip shall be installed on the circuit breaker, that causes automatic tripping if the circuit breaker is ON before engaging or withdrawing it.

  c) Auxiliary switches shall be supplied for remote position indication (connected and disconnected positions).

Multiple breakers shall have a common trip bar and trip elements on each pole to ensure that any abnormal condition on any one pole will cause all poles to open simultaneously.

Visual indication of open, close and trip conditions shall be provided. Circuit breakers shall be padlockable in the “OFF” or “Withdrawable” positions.

402.9.3 Thermal-magnetic motor circuit breakers

Thermal-magnetic circuit breakers shall be of the quick make, quick break trip type complying with BSEN 60934 and 60947 standards and shall be complete with the following:

- An adjustable thermal overload protection with automatic temperature compensation between -20° C and +60° C for open mounting and -20° C and +40° C for closed mounting.
- An instantaneous protection against short-circuit with fixed threshold 13 times the rated current.
- A minimum of three auxiliary switches that indicate pole position and a minimum of one auxiliary switch for tripping.
- A shunt trip release for remote tripping.
- A counter that indicates the number of Open/Close or Tripping operations of the circuit breaker for maintenance purposes.
- A visual indication of Open/Close/Tripped condition.
- Circuit breakers shall be padlockable in the “OFF” position.

402.9.4 Miniature Circuit Breakers

Miniature circuit breakers shall be of the quick make, quick break, trip-free type complying with BS 3781 Part 1. Circuit breakers shall be complete with thermal/magnetic or magnetic/hydraulic releases. Multi-pole breakers shall have a common trip bar and trip elements on each pole to ensure that any abnormal condition on any pole will cause all poles to open simultaneously.

Visual indication of open, close and trip conditions shall be provided. Circuit breakers shall be padlockable in the "OFF" position where specified.

402.9.5 Distribution MCB Boards

Miniature circuit breaker distribution boards shall be totally enclosed, metal clad, flush fronted units, with a hinged front door, all in accordance with BS 5486 Pt 12. The interior shall be assembled from all-insulated miniature circuit breakers with bolted connections and with switch dollies arranged for vertical operation. Phase dividing barriers shall be provided and all live parts shall be screened from the front. Circuit identification charts shall be fitted to the inside of all distribution boards.

402.9.6 Residual Current Circuit Breakers

The circuit breaker shall be arranged to isolate each live conductor simultaneously within 30ms if the residual leakage current through the device exceeds 30mA.

It shall be housed separately or incorporated into other composite enclosures, include provision for testing the tripping operation under earth leakage conditions by means of a built-in resistor and push button, and require manual resetting.

402.9.7 High Voltage Circuit Breakers And Disconnectors

402.9.7.1 Breakers

For AC circuits, circuit breakers shall be triple pole of the vacuum interrupter, SF6 or air break type as specified, suitable for the short circuit fault duty specified herein. Low voltage breakers shall incorporate a neutral link, unless in special cases a neutral pole is called for on the breaker under the specific requirements. Air or oil break circuit breakers shall be `trip-free' and the whole of the operating mechanism shall be suitable for such conditions of operation.

The whole equipment shall be robust and capable of withstanding repeated closing and opening impacts satisfactorily.

Each breaker shall be provided with the following:

a) Mechanical `Flag' indicator giving reliable indication that it is either "Off" (open) or "On" (closed).

b) Means of isolation so that the breaker may be maintained with busbars alive.

c) An operating handle that can be concealed when not required, to ensure a flush fronted appearance.

d) An adequate number of auxiliary switches with the addition of one normally open and one normally closed spare switches, all to be wired to a terminal board of approved design in the fixed portion of the switch-gear and arranged in the same sequence on all equipment.

e) Protection relays and tripping devices as specified.

f) Facilities for connection of appropriate auxiliary circuits when the circuit breaker is in the isolated position to permit operation of the breaker for test and indication purposes.

g) Key operated interlocks between breakers as specified.

402.9.7.2 Disconnectors

HV disconnectors shall be triple pole, oil free switch-disconnectors rated for fault making/load breaking duty to IEC 265, mounted on a non withdrawable chassis and enclosed in a metal clad enclosure in accordance with BS 5227 or equivalent.

The contact breaking mechanism shall incorporate expulsion quenching techniques to ensure positive arc extinction and high closing speeds to enable the switches to close onto existing short circuits without harming the equipment or the operator.

The switches shall be either manually or electrically closed and manually or electrically tripped as detailed in the Specific Requirements. All operations shall be effected with the panel door closed and include an ON/OFF indicator. Contact separation shall be clearly visible through a viewing window on the cover.

402.9.7.3 Safety Shutters

Where withdrawable circuit breaker units are used, the housing shall be arranged to accurately locate the movable portion prior to engagement and accommodate automatic safety shutters.

Each group of busbar and circuit spout orifices shall be fitted with an individual automatically operated safety shutter, the appropriate shutters being positively opened or closed when the circuit breaker is racked in or out.

When closed, the shutters shall effectively prevent any contact with either the busbar or circuit connections and seal the spouts against the ingress of dust. The shutters shall be painted in bold characters `BUSBARS' or `CIRCUITS' as appropriate, the busbar shutter being coloured red and the circuit shutter being coloured yellow (see Appendix 8).

For testing and inspection, each shutter shall be separately hand operated from the front of the unit and latched in the open position. Any movement of the circuit breakers either in or out of the housing shall automatically restore the automatic feature.

Provision shall be made for each shutter to be locked only in the closed position.

Non-withdrawable HV switch-gear shall have a three phase test access point incorporated in the design such that cable and injection tests may be carried out on each circuit. The test access point shall be fitted with a lockable cover and interlocked to prevent access to live circuits.

402.9.7.4 Provisions for Earthing

Provision shall be made for earthing the busbars and each circuit outlet through the circuit breaker, either integrally or by means of a portable device as specified; such an arrangement being suitable to withstand the full short circuit rating of the switch-gear.

Where integral earthing facilities are included, selection of the locating mechanism shall prevent the breaker being engaged into any position other than that selected. Visual indication of such circuit breaker locations shall be clearly marked, eg. "CIRCUIT EARTH", "BUSBAR EARTH", "SERVICE/ON" and "ISOLATED/OFF".

Facilities shall be provided so that padlocks can be fitted to prevent the selection of either "EARTH" positions.

Facilities shall be provided for padlocking the circuit breaker while it is closed on to an earthed circuit to prevent unauthorised tripping electrically or mechanically.

The circuit breaker truck (or carriage) and oil tank if applicable, shall be effectively earthed when in the "SERVICE/ON" position.

HV switches shall have facilities for earthing the circuit by means of a selector and the ON, OFF and EARTH positions shall be visibly indicated, appropriately labelled and provided with locking facilities in each position. Inspection windows shall be provided so that the position and condition of the selector contacts and insulators can be observed.

402.9.7.5 Interlocks

Each circuit breaker unit shall be provided with mechanical interlocks to prevent incorrect operation or accidental contact with live metal, and to protect the equipment and operator from the dangers of mal-operation and designed to prevent the following where relevant:

The circuit breaker being closed unless it is in the fully- engaged or fully-withdrawn position.

The circuit breaker being engaged and plugged into the busbar and circuit spouts unless the tank is bolted to the top-plate.

The circuit breaker being engaged or withdrawn unless the main contacts are open.

The circuit breaker unit being withdrawn from or pushed into the unit housing unless the breaker is in the fully-withdrawn position.

The circuit breaker being positioned in the unit in any position other than that indicated on the locator.

Access to voltage transformers unless they are in the isolated position.

402.9.7.6 Handling Track

For each switchboard and different type of breaker supplied, one purpose designed, manually operated lifting and handling track shall be provided to enable safe removal of a circuit breaker from its compartment.

402.9.7.7 Switch Oil

The first change of switch oil shall be provided for each oil circuit breaker or switch. An oil level indicator shall be provided on each tank with maximum and minimum limits marked.

402.10 ELECTRIC GENERATORS

402.10.1 Alternators

Alternators shall be star connected machines producing a 3 phase, 4 wire, 50 Hz supply at the specified rated voltage within a standard waveform deviation, when being driven at the rated speed and connected to the plant load specified herein.

The alternator shall be continuously rated and generate at 380 volts, 3 phase, 50 Hz, with the neutral point connected to an individual earth bed.

The alternator enclosures shall be protected to IP22 Bs.4999 part 20. They shall be suitable in all respects for operating in the climate conditions specified in the tender document.

The insulation of the stator and rotor shall be in accordance with British standard class "H", but the alternator shall be designed for a class "E" temperature rise. The efficiencies of the alternator shall be stated in the tender and shall be determined in conformity with the procedure laid down in BS.4999 Part 33 and shall be manufactured in accordance with BS.5000 Part 99.

Each alternator shall be capable of satisfactorily providing an output 10% percent in excess of the BS rating for one hour in any period of 12 hours consecutive running.

The rotating parts shall be statically and dynamically balance to close limits.

Each alternator shall be fitted with anti-condensation heaters of a size to maintain the temperature of the windings 5°C above ambient. Each heater, shall be provided with a switch and automatic control to disconnect the heater when the alternator is running.

Terminal boxes shall be provided and arranged with sealing chambers for the reception of the cables detailed in the relevant sections of the specification. Terminals shall be clearly marked to give phase identification.

i) Regulation

The generator automatic voltage regulation system for single set running shall be capable of maintaining the voltage for all loads between no load and rated load at rated power factor.

Due allowance shall be made for the current peaks associated with starting the motor loads connected to the alternator, and the regulation system shall be designed such that the transient voltage reduction following the load application does not exceed 15% of the rated voltage and shall be restored to within 97% of rated voltage in less that 1.5 seconds. The transient voltage rise when the rated load is thrown off shall not exceed 25%.

Where voltage regulation equipment is mounted on the alternators, the components shall be readily accessible and detachable for servicing, having terminations separate from the main terminals.

ii) Excitation

The alternator shall be the brushless self-excitation type with rotating armature and verifier assembly mounted on the alternator shaft, electrically interconnected with the field winding. Radio noise suppression shall be in accordance with BS 800 and the exciter field shall be safely discharged when the alternator is tripped.

402.10.2 Generator Panels

The panel shall be easily accessible, protected against fluid projections and fixed on shock absorbers near the engine.
It shall include :

- 3 ammeters
- 1 voltmeter
- 1 frequency meter
- 1 oil pressure gauge
- 1 water thermometer
- 1 oil thermometer
- Push-buttons : on, off, and emergency stop
- 1 hour meter
- 1 contact key

402.10.3 Mains/Standby Supply Changeover

The changeover section shall monitor the three phase voltages and Neutral of each of the two incoming supplies and automatically close the 4 pole contactor to the healthy supply. The two incoming supply contactors shall be healthy supplies.

Where a bus-section switch is provided for manual switching arrangements to allow both supplies to be utilised without paralleling, the contactors must be electrically interlocked between each other and the bus-section switch. The bus-section switch will normally be closed so that all plant is fed from the healthy supply. If however the bus-section switch is opened, the anti-paralleling interlock will be defeated and it shall be possible to close both incoming contactors for exercise purposes.

Voltage monitoring settings shall be adjustable and nominally set to operate on a rising voltage of 90% nominal, with low/high voltage settings at ±15% nominal on each of the three phases.

a) Automatic Operation

Mains Supply - Closing the incoming isolator or restoring a healthy supply will initiate the closing of the Mains contactor via the monitoring relays, subject to the generator operating condition.

Momentary supply drop-outs up to 5 secs. shall allow the plant to resume without further action. Breaks of supply greater than 5 secs. shall initiate the generator supply. Delayed start timer setting to be adjustable 0-3 min.

On restoration of mains supply a minimum period of 10 sec. shall elapse before a signal is given to stop the generator. Delayed stop timer setting to be adjustable 0 - 3 min.

Generator Supply - After the generator has been initiated, the monitor relays shall control the closing of the generator supply contactor to the load. The generator shall continue to run until signalled to stop by the restored Mains supply. A timer provided by others in the generator control panel shall ensure that the generator shall run for a minimum time on-load of not less than 30 mins, (adjustable 0 - 60 min). All timers shall be set to suit operational requirements.

b) Manual Operation

If the generator is to be connected to both halves of the switchboard (bus-section closed) whilst the Mains supply is still available, the Mains supply switch shall be opened and the generator will receive its automatic start signal due to apparent loss of Mains supply. The generator will start and take on load automatically as if for a normal mains failure. The generator will continue to run until the Mains switch is closed, generator shutdown will then occur as defined for automatic mode.

If the generator is to be connected to its own half of the switchboard only, with the other half still fed form a healthy Mains supply, opening the bus-section switch will allow both contactors to be closed. The generator must then be manually started from the 'Generator Run-Up' button as mains failure will not be detected. When the generator is running and ready to take load, the generator supply contactor will close automatically and the drives may be started in sequence as required. The generator will continue to run until the 'Generator Run-Down' button is operated, this will immediately stop the generator and de-energise its supply contactor, allowing the Mains supply contactor to be restored after the bus-section switch has been closed. The generator minimum run timer being over-ridden for the manual facility.

If the generator is to be run off-load only, then its incoming supply switch may be opened, alternatively the bus-section may be left closed, thus preventing the generator contactor from closing whilst the Mains supply is in use. The 'Generator Run-Up/Run-Down' buttons or the Start/Stop buttons on the local generator control panel shall be used.

c) Restoration of Loads

After any changeover of supplies, automatic or manual, the pump motor loads may be restored automatically or manually (remotely or locally) as specified but with sequential 20 sec. re-start delay timers incorporated in each pump starter circuit to prevent Co-incident starting surges.

402.11 ELECTRODES

402.11.1 Electrode Mounting

The electrode heads shall be mounted on a suitable support bracket at a height well above the expected maximum water level.

Intermediate steady brackets shall be provided and fitted for every 2m of electrode length, insulated lengths of electrode being fitted where these are used.

Support brackets and steady brackets shall be hot dipped galvanised to BS 729 or otherwise protected to prevent corrosion.

402.11.2 Heavy Duty Electrodes

Each electrode shall comprise a single element mounted in an insulating high impact phenolic moulding, impervious to corrosion and having separate fixings for the flange mounting base and for the cover.

The base shall have a 20mm screwed conduit entry and be suitable for accommodating the electrodes, and incorporate provision for adjusting the electrode length by means of a substantial clamping collar which shall also have a provision for terminating the cable conductor.

A sealing gasket shall be fitted between the base and cap and the whole head shall be sealed to prevent the ingress of water after installation is completed.

The electrodes shall be formed of 3/4" BSP galvanised steel tubes (approximately 27mm diameter) sealed at one end and cut to suite the specified length, cut ends being dipped or coated with galvanising paint or similar. Where intermediate steady brackets are required or when otherwise specified, the electrodes shall be sheathed with an insulating material to within 150mm of the electrode tip.

Spacing between electrodes and to the adjacent wall shall be not less than 150mm.

402.11.3 Light Duty Electrodes

Each electrode shall be mounted in an insulating moulded body having a 20mm screwed conduit entry and a screwed cover such that the whole head may be sealed to prevent the ingress of water after installation is completed.

The electrodes shall be formed from not less than 6mm diameter stainless steel rod and should not exceed 1.5m in length for light duty applications. Spacing between electrodes and to the adjacent walls shall be not less than 100mm.

402.11.4 Electrode Circuits

All electrode circuits and components shall comply with BS 5345 and the BASEEFA requirements for an intrinsically safe system for Apparatus Groups IIA and IIB.

The system shall operate by the circulation of an AC current when the circuit is completed by the liquid coming into contact with the electrode, this current operating a relay to initiate the events specified herein. The relay operation shall incorporate a five second time delay 'On' and 'Off' to allow for spurious initiation.

Intrinsically safe electrode circuits shall be completed by a separate return electrode for each circuit.

402.12 LOCKS & KEYS

402.12.1 General

Lockable selector switches or panel doors in a multi-unit installation shall employ a common interchangeable operating key but keys for each function may be non-interchangeable, subject to the approval of the Engineer.

For each key pattern employed, three keys shall be provided; each having a permanently attached brass identification label, embossed with the following:

a) key number
b) location of lock/item of equipment ref.

Loose padlocks and keys for security locking switchgear, isolators, shutters etc. shall not be included but will be provided by the Client to suit their master key suite for permit locking. Hasps shall have not less than 9mm diameter holes suitable for 6mm diameter shackles.

402.12.2 Padlocks

Padlocks shall be provided for independently securing busbars and circuit shutters in the closed position and also for locking each circuit breaker or switch in the open position. A padlock and key, or similar device, shall be provided to lock each circuit breaker closed when in the earth position. Padlocks and keys shall also be provided to lock any isolator and earthing device handles in either the open or closed position, such that the mechanism is inoperative unless the locks have been removed. All padlocks in any station shall take the same key.

Glass fronted lockable key boxes, with labelled hooks, shall be provided for each switchboard.

402.12.3 Key Cabinets

Key cabinets shall be provided to accommodate, on suitably numbered/coloured, adjustable hook bars, one set of all the above keys and padlocks. The keys shall be fitted with corresponding number/colour coded tabs. The cabinets shall be of stove enamelled sheet steel material, suitable for surface wall mounting and be fitted with lockable hinged cover doors.

402.13 LIGHTNING PROTECTION AND GROUNDING SYSTEMS

402.13.1 General

Lightning protection systems shall be designed to withstand direct and indirect lightning strikes.

Lightning protection systems shall consist of the following:

- Air termination network or rod-type lightning conductor.
- Down conductors.
- Ground termination network.

Ground termination shall be acheived by installing electrode rods (in pits) connected to the bottom of the down conductors using tape tails.

402.13.1.1 Joints

Any joint other than welded represents a discontinuity in the current conducting system. The lightning protection system must have as few joints as possible.

Joints should be mechanically and electrically effective, e.g. clamped, screwed, bolted, riveted or welded with overlapping joints, the overlap should not be less than 60 mm for all types of conductors. Contact surfaces should first be cleaned and then inhibited from oxidation with a suitable non-corrosive compound. Bi-metallic joints should be thouroughly cleaned using a separate abrasive for each type of material.

All joints should be protected against corrosion or erosion from the elements of the environment.

402.13.1.2 Bonds

Bonding shall be used to prevent side-flashing.

Careful attention shall be given to the metals and items being bonded.

A bond should be mechanically and electrically effective and protected from corrosion and erosion either by selection of material or by protective measures.

402.13.2 Lightning Protection Systems

402.13.2.1 General Requirements

Down conductors

Down conductors shall be copper flat strip and have a minimum 25x3 mm² c.s.a. They shall be fixed with leaded gunmetal clamps, secured by phosphor bronze screws or bolts. Each down conductor shall take the most direct route from the air termination network to the earth termination and be provided with a bolted test joint in such a position that, whilst not inviting unauthorized interference, it is convenient for testing purposes.

Plates indicating the position, number and type of earth electrodes should be fitted above each test point.

Down conductors shall be protected with galvanised steel covers between the control junction and the ground up to 2 m above ground.

Equipotential bonding system

Buildings with a lightning protection system must be included into the main equipotential equalisation by means of the main earthing bar or equipotential bonding bar. Lightning protection equipotential bonding for the conductors of the energy network must be accomplished as close as possible to the point of entry of the mains into the building.

Ground termination network

Earth electrodes of 16 mm² copper bonded, steel cored rods shall be deep driven into the ground as close as practical to the structure. The rods shall be installed in sections connected by screwed couplers and driven to a sufficient depth to acheive a combined resistance to earth not greater than 3 ohms.

The screwed couplers shall be long length aluminium bronze material, counterbored to protect the threaded ends from damage and corrosion.

The ground termination network shall be able to carry high currents repeatedly.

Electrodes may be one of the following types:

- Deep driven rods
- Radial strip
- Solid plate or mat.

Step and touch voltages on the surface of the ground in the vicinity of earth electrodes must be restricted to a maximum value of 5% the voltage gradient.

402.13.3 System using air termination network

The protection system shall be designed and installed in accordance with BS 6651. No part of the roof should be more than 5 m from the nearest horizontal conductor. For large flat roofs, this will be achieved typically by an air termination network mesh which dimensions are adequately chosen. On a reinforced concrete structure, the air termination network should be connected to the reinforcing bars in all positions required for down conductors.

All metalwork on or very close to the structure shall be bonded to the lightning protection system. Where connection between dissimilar metals are made, precautions shall be taken to prevent corrosion.

If portions of a structure vary considerably in height, any necessary air termination networks for the lower portions, should be joined to the down conductors of the taller portions in addition to being joined to their own down conductors.

It must be noted that at all times adequate conductor fixings must be used in conjunction with the recommended fixing centres.

402.13.3.1 Lightning protection zones

The zone concept of integrating external and internal lightning protection systems through equipotential equalisation shall be followed to ensure an effective and complete protection system of all sensitive equipment susceptible to damage and failure from switching operations in power networks, or from the effects of lightning, together with overvoltage hazards due to electrostatic discharges.

All the cables entering the building must be incorporated into the protective equipotential bonding system at the interfaces between lightning protection zones.

The active conductors of power supply and computer networks shall be integrated into the protective equipotential bonding system via special lightning arresters.

Local equipotential bonding must additionally be ensured at every other interface between zones within the building. Equipotential bonding of active conductors is realized with the aid of overvoltage arresters at these points.

The local equipotential bonding bars are to be connected to each other and to the main lightning protection equipotential bonding bar.

402.13.4 Systems using rod lightning conductor

402.13.4.1 Franklin type

This type of protection consists of a lightning conductor inert rod mounted on a mast and connected to a ground post by down conductors.

Location and height shall be determined by the Contractor and approved by the Engineer to ensure that the protection of the entire plant is in accordance with NF C 17-100.

The lightning conductor shall be tied with galvanized steel clamps on the mast to withstand vibrations and mechanical stresses.

402.13.4.2 Early streamer emission type

The same installation rules of the Franklin type apply for the early streamer emission type with the following additions:

- No radioactive sources shall be used.
- The high voltage/frequency emission components shall be inaccessible.
- No external electrical or mechanical energy supply shall be needed: The system shall be self-contained, drawing its energy from the ambient electric field existing at the time of the storm (5 to 20 KV/m).
- The radius of protection and installation height shall be determined in accordance with NF C 17-102.
- A test report from a high voltage laboratory shall be submitted to the approval of the Engineer as well, confirming the initiation advance ΔT of the lightning conductor and the efficiency of the self-contained electronics in the lightning conductor.

402.13.5 Overvoltage protection

Electrical and electronic equipment shall be protected against surges or transients generated by switching operations, electrostatic discharges and induction, etc... by the use of graded lightning and overvoltage arresters.

Other grounding systems such as that for building, plumbing, power supplies, information processing etc... shall be taken into consideration upon designing the complete protection system.

Compatible overvoltage devices for ‘line-side’ protection, that includes basic, medium level and detailed protection, shall be installed and shall be of the same brand.

These overvoltage devices shall be installed according to BS EN 60099 and to the manufacturer’s recommendations and shall have the following characteristics:

- Modular design
- Visual fault indication
- Remote signalling module
- Replacement of active module (varistor) without interrupting the power supply
- Negligeable leakage current
- High discharge capacity
- No follow current when the surge voltage has died down
- Short response time

Telecommunication systems, data interfaces, electronic networks, etc... shall be protected with adequate overvoltage protection devices.

402.13.6 Grounding system

Grounding system shall consist of the following:

- Earth points and underground connections (main grounding network)
- Electrode inspection pits
- Collector pits
- Protective conductors

402.13.6.1 Main grounding network

The main grounding network shall be of the mesh type, therefore the rupture of an underground conductor in a given point of the installation shall not lead to the isolation of this point from the ground.

The main grounding network shall consist of rings made by a cable laid within the structure’s foundations and surrounding each part of it. These rings are connected to one another by at least two separate connections. No cut-off or isolating device shall be inserted between these conductors.

Where the execution of rings is not possible, the contractor may adopt other standard alternatives:

- Crows foot earth configuration

- Solid plates
- Radial strip electrodes
- Matrix arrangement of deep driven parallel earth rod electrodes.

The resistance of the main grounding network compared to a reference zone located outside the influence zone of the mesh network shall not exceed five ohms.

Rings, and ground networks in general shall be buried in trenches at least 1 m below ground level.

402.13.6.2 Electrode inspection pits

Connections with rings, links and other auxiliary grounding systems shall be done exclusively inside standard inspection pits.

These inspection pits shall allow location of main ground points, verification of electrical continuity and measurement of resistivities.

402.13.6.3 Collector pits

Collector pits shall be erected as required in the grounding system. They shall contain a grounding collector made of a tinplated copper frame of appropriate c.s.a allowing the connection of all protective cable ends.

The grounding collector shall ensure at least a double connection with the grounding network.

402.13.6.4 Protective conductors

They shall be of appropriate c.s.a and constitute with the grounding collectors a radial network. Hence, series grounding connections are strictly prohibited.

Protective conductors shall be laid exposed in gutters or in a sleeve built-in in masonry or concrete works.

Radius of curvature of the protective conductors shall not exceed 8 times its overall outside diameter.

Protective conductors rising from the floor, shall be protected by a sleeve protruding 50 cm above ground level.

402.14 HEATERS & THERMOSTATS

402.14.1 Water Heater

Single point water heaters shall be thermostatically controlled free outlet 'single point' heater suitable for wall mounting. The water inlet shall be 0.5" BSP fitted with a control tap and the outlet swivel spout shall have a reach of approximately 300mm. The heater shall have a capacity of approximately 1.5 gallons (7.0 litres) and an electrical loading of approximately 3kW.

402.14.2 Space Heaters

Wall mounted single tier tubular heaters rated at 250 watts/metre and suitable for 220V operation shall be provided.

The heaters shall be mounted approximately 300mm above floor level. They shall be directly connected to heater circuits controlled by the room thermostat, the final connection to the heaters being made by means of flexible conduit and a protective conductor. The flexible conduit shall enter from below the heater.

402.14.3 Space Heater Thermostat

The thermostat shall be a surface mounting 14 Amp bi-metallic strip type, adjustable over the range 0-30°C and lockable to prevent unauthorised adjustment of the setting.

The room thermostat shall be mounted approximately 2.0m above the floor level.

402.14.4 Electric Trace Heating

Heating cables shall comprise a self-regulating, conductive polymer core or double insulated heating elements within a waterproof outer PVC sheath having sealed ends with a cold lead at one end. The cable shall have a flat section to provide efficient heat transfer.

The cable shall be straight laced along the underside of pipes and secured with cable ties at 300mm spacing or be spiralled around the pipe and secured at each end. All heating cable must be in intimate contact with the pipe and must not be overlapped on itself, additional ties being positioned on either side and close to all flange joints. To avoid mechanical or leakage damage, the cable shall be run over the sides of flanges at 90° to the invert on horizontal pipe runs.

After any thermal insulation has been fitted, wiring labels shall be fitted in prominent positions on the pipework to indicate the presence of trace heating.

402.14.5 Trace Heating Thermostat

A wall mounting, air sensing thermostat set at 5°C shall be provided and arranged to switch on the heater for frost protection. If non-self-regulating heating tapes are used and where lagging is applied, or on PVC pipework, a thermostat shall be located on the pipework and arranged to switch off the heater if the temperature exceeds 60°C. Liquid filled sensing bulbs and capillary tube connections to the thermostat shall be of stainless steel with a stainless steel flexible sleeve fitted over the capillary tube for mechanical protection.

The air measuring thermostat shall be mounted on the outside wall, 600mm above ground level and adjacent to but not above the protected pipework.

Enclosure and terminal arrangements to be as specified for field mounted equipment.

402.15 UNINTERRUPTIBLE POWER SUPPLY (UPS)

A rectifier/battery/inverter system shall be rated and arranged to provide a 'no-break' supply to the specified loads.

The UPS shall incorporate maintenance free, lead acid, sealed batteries and operate in a continuous mode to protect the connected loads from AC supply interruptions and irregularities. The general technical characteristics of the UPS are as follows unless otherwise specified:

- Output	:	110 V / 220 V ± 5%, 50 Hz ± 0.001 (crystal control), sinusoidal
- Efficiency	:	inverter ≥ 85% - Total ≥ 80%
- Autonomy	:	3 hours at optimum power output
- Total distortion	:	maximum 3% at full load
- Power supply	:	110 V / 220 V ± 10%, 47-53 Hz
- Power factor	:	inductive load 0.6 to 1 capacitive load 0.85 to 1
- Overload	:	125% for 3 seconds 150% for 1 second 200% for 50 ms
- Protection	:	Circuit breaker for: battery low voltage - overloads
- Signalling	:	- Inverter : 'ON' - Power supply voltage : 'ON' - Battery voltage - Overload indicator - Ammeters, voltmeters - Audible alarm

The unit shall incorporate a static by-pass switch arrangement such that in the event of failure of the inverter, it shall automatically transfer the load to the by-pass supply with no loss of continuity in supply. This unit shall monitor the mains and output frequencies to maintain synchronisation within ±0.5 Hz and ±5% voltage. Where these tolerances are not maintained, the static by-pass shall be inhibited to prevent out of sync switching. Where generator sets are to be connected, a frequency tracking inhibit switch shall be included.

A manual by-pass switch shall also be provided to enable the UPS to be taken out of service for maintenance. No feedback shall be possible and any live parts shall be fully shrouded.

The transformers of remote control, signalling..., circuits shall be class I, insulation class E and according to standards. They shall be installed in the control panel, non insulated, with terminals protected by an adequate screen.

The UPS shall be selected according to the required maximum power, taking into consideration voltage drops, climatic conditions and necessary derating.

During mains failure, the battery will take over the supply via the inverter. On re-connection of the mains supply, the system shall automatically revert to its normal operating mode and the battery be recharged to its full operating capacity.

The unit shall be protected at the upstream by a thermo-magnetic circuit breaker, and at the downstream by a differential thermo-magnetic circuit breaker 30 mA.

A galvanic isolation of inputs-outputs shall be ensured. Circuit breakers shall be equipped with a fault signalling device.

Distribution towards the different parts shall be carried out by means of distributors.

The set of relays shall be of low in-rush current.

Controls, metering and indications shall be provided on the panel front and arranged in an approved manner.

a) Start, Stop and Reset push buttons.

b) Metering shall be provided for:

1) battery voltage
2) battery amps (centre zero)
3) output voltmeter
4) load ammeter

c) Status indications shall be provided for:

Normal conditions - White	**Fault conditions - Amber**
Mains on	Battery volts low
Boost charge	Charge failure
Inverter on	Inverter failure
By-pass supply available	Static by-pass inhibited
By-pass supply to load.	

All fault indications shall provide 'volt-free' contacts for remote indication.
On/Off control switches shall be provided within the panel for:

Mains input
Battery isolator
By-pass supply
Boost charge

When isolating the UPS for maintenance, separate mains input and battery supply isolators shall be provided, interlocked such that the battery isolator cannot be closed before the mains switch is closed (to limit stress on the storage capacitors).

The UPS output shall be protected against under/over voltages and overcurrent during load transfers. The UPS shall be capable of satisfactorily withstanding an overload of 125% for 10 minutes and maintain output frequency stability of $\pm$5% for 100% load changes.

Current limiting and over-voltage protection shall be included in the charger circuit together with charge rate adjustment to suit the battery manufacturer's recommendations, with automatic initiation of a timed boost charge as required.

The harmonics generated shall be restricted by suitable filters to be within the tolerances defined in Engineering Recommendations G5/3 "Limits for Harmonics in the UK Electricity Supply System".

The charger (rectifier) shall be sized to suite the maximum total power requirements of circuits. The rectifier output shall also include filters to reduce DC ripple to the batteries to maximise battery life.

The UPS shall preferably be located within the Control & Monitoring Panel but where the panel is a separately mounted, free-standing unit, all construction, component and finish details shall comply with those specified for the switchboard panels.

402.16 BATTERIES & CHARGERS

402.16.1 Battery Charger

The battery charger shall operate from the mains supply and be suitable for the battery provided and shall include overcurrent protection and automatic voltage regulation irrespective of the load on the battery. Where permanent loads are connected, the charger shall be capable of supplying a normal float charge designed to meet the standing loads and maintain the battery in a fully charged condition. Provision shall be made for a boost charge, selected by means of a Normal/Boost switch mounted within the panel with a label adjacent giving instructions on the use of the boost control.

The charger shall incorporate a provision for adjustment of the charging voltage and have protective devices to initiate the "Battery Fault" indication on the specified panel in the event of charge failure and low battery voltage. Mounted on the front panel shall be a mains supply indication lamp and meters showing the charging voltage and current.

When associated with engine starting duties, the charger shall be automatically isolated during the engine starting procedure. During engine operations, battery charging shall be automatically maintained by an engine driven generator working through a regulator and cut-out.

402.16.2 Starter Battery

The battery shall be a 24V lead acid, stationary, high performance, low maintenance Plant type suitable for Standby engine starting duty and continuous normal charging.

Its capacity shall be sufficient to provide at least three successive 10 second attempts to start within a period of 2 minutes at 0°C.

The battery shall be accommodated securely in a wooden stand supporting a protecting cover, all finished with 2 coats of black chlorinated rubber paint.

402.16.3 Battery Supplies

Batteries for switchgear, control and alarm duties shall be of pocket plate nickel cadmium structure with an alkaline electrolyte and shall be suitable for constant trickle charging.

Each trip battery shall be rated for performing three successive tripping duties and for alarm relay circuits required for the associated circuit breakers. The trip battery shall not be used for other than these purposes.

402.17 POWER FACTOR CORRECTION

Unless otherwise specified, a power factor correction capacitor complying with BS 1650 and suitable for operation over the temperature range -10°C/+40°C shall be connected to improve the overall power factor of each machine to not less than 0.9 when running at full load.

Each capacitor bank shall be fitted with HRC fuse protection enclosed within a sheet steel housing having a terminal box with separate bolted access cover and an external earthing terminal.

Means shall be provided for monitoring fuse failure visually. Striker pin fuses shall be provided and arranged to operate a trip bar which shall initiate an alarm contact for remote indication. Resistors shall be fitted to provide a controlled discharge on de-energisation except where such discharge is effected by the machine windings.

The terminal boxes of motors and capacitors shall be labelled with “Traffolite” type labels, black letters on yellow background, to read in Arabic and English.

"WARNING LIVE TERMINALS- ISOLATE BEFORE REMOVING COVER".

"WARNING - EQUIPMENT CONNECTED TO STORED ELECTRICAL CHARGE.
ISOLATE AND EARTH ALL TERMINALS BEFORE HANDLING".

403. CABLING & WIRING

403.1 ELECTRICAL CABLES INSTALLATION

403.1.1 General

The electrical installation shall comply with the current edition of the Regulations for Electrical Installations published by the Institution of Electrical Engineers (IEE Wiring Regulations) and the requirements specified herein where these differ from the IEE Wiring Regulations.

The installation shall be arranged in a neat and orderly manner which may involve running out of direct lines in order to conform to building outlines etc. and to utilise any holes provided for cabling purposes in the structure. Unnecessary crossing of cables will not be accepted and due care should be given to this when selecting runs. Each cable shall be in one continuous length and no straight through joints will be permitted except as agreed with the Engineer.

It shall be the entire responsibility of the Contractor to program the whole of his work and Co-operate with other contractors to ensure that the various parts of the electrical installation are executed at the proper stages of the construction, special care being taken with concealed work.

Care should be taken that servings and sheathings of cables are not damaged during installation. Should any part be damaged, the damage shall be made good to the entire satisfaction of the Engineer. Cables shall only be installed when the ambient and cable temperature is above 0°C and has been so for the previous 24 hours.

Cables shall, wherever possible, be arranged to enter equipment from below, particularly equipment located externally or in damp situations. Cables entering cubicles provided with sealed covers of timber or sheet steel shall be accommodated by drilling or dividing the covers with clearance holes as necessary to allow the cable to pass through and be terminated at glands or gland plates provided within such cubicles, so that the covers when replaced prevent entry of dust and vermin.

All cables shall be of suitable voltage grade, with stranded copper conductors, selected for the climatic conditions specified:-

i-	Ground Temperature	30°C
ii-	Cables above ground, not exposed to direct sunlight Air Temperature	40°C
iii-	Cables above ground and exposed to direct sunlight Air Temperature	70°C

Each cable shall be of sufficient rating for its duty under normal, fault and site installation conditions. To assess the rating and cross-section required for each cable, the following factors must be considered as a minimum.

i- Fault level.
ii- Conditions of ambient temperature relevant to method of laying.

iii- Voltage drop.
iv- Voltage drop in motor circuits due to the starting method.

v- Over current settings of circuit breakers.

vi- Disposition of cabling, whether in air, ducts or soil.

Derating factors shall be applied for all cables at the following conditions : -

a- Cable depth 0.6 metres minimum

b- Cable grouping to be in accordance with the relevant IEE regulations.

c- Cable in air to be in accordance with the relevant IEE regulations.

Where cables are run in conduit or trunking, any requirements or I.E.E. Regulations must be complied with.

Where a neutral conductor is required, its cross-sectional area shall not be less than that of the phase conductors, unless otherwise specified. Each and every mains supply cable shall be provided with an individual earth continuity conductor, which shall be of sufficient cross section area being either one core of a multicore cable or a separately run, P.V.C. insulated (green, or green/yellow) stranded single core cable sized in accordance with the regulations. The use of cable armouring, conduits, water or other service pipes as the only means of an earth continuity path is strictly prohibited.

Prior to dispatch to site the supplier shall pass to the Engineer, in triplicate, copies of the cable manufacturers test certificates for approval.

Each cable shall have its individual cores identified along their entire length by permanently printed numerals or letters. At every point of termination, core identification shall be carried out using an approved system of ferrule markers. At points of interconnection of wiring at which a change of numbering is unavoidable double ferrules shall be provided on each wire.

Any change of numbering shall be recorded on the wiring diagrams of the equipment at which the change is made.

When more than one cable is to be terminated at an item of equipment, particular care should be taken to ensure that all cables to the equipment are routed from a common direction and each is terminated in an orderly and symmetrical fashion. Each and every cable shall be permanently identified at each end by its cable number, as noted within the schedules. The identification label shall be of adequate size and style to a pattern approved by the Engineer and shall be securely fixed to its relative cable.

In the event of any armouring or serving fault being made it will be the responsibility of the Contractor to repair or make good any such faults to the satisfaction of the Engineer. Where any such fault occur, these shall be made known to the Engineer and subsequently recorded on the final record drawings.

All L.V. and H.V. cables shall be delivered on robust cable drums which shall bear the full details of manufacturer, size, length and insulation and shall be offered to the Engineer for inspection prior to installation.

403.1.2 Installation of visible Cables

All visible cables shall be mounted as follows:

a) Cables shall be installed on cable tray in one layer and shall in no case be superimposed. Each cable tray, shall have a 25% reserve in order to allow for the installation of future cables. Vertical sections shall be fitted with cable fixing devices.
b) Cables shall be fixed on masonry along walls by means of galvanised steel brackets or other means proposed by the Contractor and approved by the Engineer.
c) Beneath ceilings, cables shall be held by substantial supports. The supports shall be sufficiently close to avoid droop of the cables.

403.1.3 Insulated Wires

All wires and connection devices shall be accessible for inspection and replacement as required. They shall be so set out and installed as to allow handling without causing any mechanical deterioration.

All wires shall be installed entirely inside conduits.

The pulling of wires in conduits shall be carried out carefully in order not to damage the insulator. It is forbidden to use oils, grease or any other fluid for facilitating the pulling of wires, the contractor can however use powder of an approved type.

403.1.4 Other Conditions

Lengths of cables mounted between ground and a height of 2.50m and those crossing masonry shall be installed inside galvanised steel tube.

403.1.5 Segregation of Duties and Services

Cables of different circuit categories shall be segregated as defined in the IEE Regulations. Instrument control cabling shall as far as possible be routed separate from electrical power cables and long parallel runs to these or pipework should be avoided. Where parallel routes and crossovers are necessary, a minimum separation of 250mm shall be maintained. Power cables shall not occupy the same ducts as instrument cables.

Similarly, separation between the three categories of instrument cables shall also be maintained as scheduled below:

	Separation		
Categories to BS 6739	**Cat 1**	**Cat 2**	**Cat3**
CATEGORY 1 Instrument power & Control (over 50V, under 10A, AC or DC	----	200 mm	300 mm
CATEGORY 2 High level signals (5V to 50V DC)	200 mm	----	300 mm
CATEGORY 3 Low level signals (Less than 5V DC	300 mm	300 mm	----

Only conductors carrying signals of the same category shall be contained within any one multicore cable. Similarly, conductors forming part of intrinsically safe circuits shall be contained within multicore cables reserved solely for such circuits.

All screens for instrument cables shall be earthed at one point only, preferably at the main control centre.

403.1.6 Intrinsically Safe Circuits

Circuits complying with the requirements of BS 5345 for intrinsically safe circuits shall be arranged such that all cables are identified and segregated as detailed in BS 6739.

Conductors forming part of an intrinsically safe circuit shall only be contained within multicore cables reserved solely for such circuits and must be terminated separately.

Intrinsically safe circuits shall be connected to a separate earthing system as detailed in BS 6739 and any shunt diode barriers shall be installed in accordance with the certification requirements.

403.1.7 Galvanising and Fastenings

Where manufactured or purpose-made steelworks, ladder, racking, tray supports and all fixings nuts, bolts and washers are specified as galvanised, this shall mean hot dipped galvanised finish to BS 729 as far as practicable. Bolts and nuts shall be in matched condition.

Fixings screws for boxes, saddles, clips and other accessories shall be of brass or other non-corrodible type eg. cadmium plated steel.

403.1.8 Protection of Exposed Cables

Where cables emerge through steel platforms or concrete floors, the Contractor shall provide and position protective curbing or sleeves made from galvanised material extending 75mm above finished floor level. Sleeves shall be finished flush with the underside of the floor. Final details shall be agreed with the Engineer on site in respect of all situations.

Cables rising into or against floor mounted equipment shall be secured to the equipment in a neat manner to ensure that the cables are properly supported and that no undue strain is put on the cable termination or the plant. Where vibration or expansion is a consideration, adequate precautions and vibration loops shall be made at the appropriate position.

Where cables emerge in an area exposed to vehicular traffic and no overhanging projection exists up to one metre above ground level, a galvanised steel pipe or protection cover fabricated from 3.0mm (10 SWG) galvanised mild steel (or heavier as appropriate) shall be provided and fixed to the associated structure for a minimum height of 1.5 metres above the local finished ground level.

403.1.9 Cutting Away and Making Good

The Contractor shall be responsible for marking out the agreed positions of all chases, holes and fixings required for the passage of cables and conduit, and shall arrange with the Main Contractor for making good with a weak mix of concrete.

The Contractor shall carry out all the necessary drilling for fixing up to 25mm diameter in the building fabric for the support and fixings of all items supplied or specified herein. Such work shall be carried out in a neat and workmanlike manner without unduly defacing concrete or brick surfaces. The use of stud fixings employing cartridge guns will not normally be permitted.

Where indicated on the Specification drawings, holes have been incorporated in the structures for the passage of cables and any additional cutting away and making good necessary to such structures will be done by the Main Contractor with the agreement of the Engineer.

403.1.10 Termination of Glanded Cables

All cable compression glands shall be fitted by the Contractor, with the insulated conductors and sheathing being carried through the gland. The sheathing shall be preserved where required within the equipment and the insulated conductors properly connected to the terminals of the equipment concerned.

The armouring shall not be cut off short of the gland but shall be properly laid up and secured under the clamping ring provided. The gland shall be fitted finally with an overall PVC sealing sleeve.

All cable tails shall be of sufficient length to connect up to the equipment terminal boards, and in addition to making off the gland the Contractor shall strip, insulate, ring through and identify the individual cores, fit suitable termination lugs, ring or spade crimps or bootlace ferrules as appropriate, and fit numbered reference ferrules, lace the tails in a workmanlike manner and finally connect up.

All spare conductors within multi-core cables shall be terminated as shown on the connection diagram or be folded back with sufficient surplus to allow them to be connected if required in the future.

403.1.11 Lead Sheath Cable Terminations

The Contractor shall submit to the Engineer for approval the proposed method for terminating lead sheathed cables. Terminations must ensure that moisture cannot creep along the cores of the cable nor in between cores.

Where cable tails are to be brought out, cores shall be cut back below the level of the sealing compound and connected to the tails using a brass ferrule sweated to provide a solid damp and oil migration barrier between tail and core.

Paper insulated tails shall be double half lapped with an approved non-hygroscopic insulating tape. Alternatively for LV cables, instead of an approved tape, a length of temperature sensitive, PVC sleeving may be heat shrunk over the tail, joint and cores.

The continuity of armoured cables shall be maintained by an efficient bond between the cable armour, the gland and the metalwork of the equipment at which the cable terminates, in order that a reliable path is provided for fault currents.

When the lead sheath has been wiped on to the cable gland, the steel armouring shall be brought over the wiped joint and clamped to the top of the gland to provide additional earth continuity and mechanical strength to the plumbed joint. The armour clamp shall sandwich a copper braid between the clamp and the armouring to ensure a bedded connection.

Compression glands shall be to an approved pattern providing adequate bonding and armour clamping facilities.

Cable cores shall be fitted with suitable termination lugs and be phase coloured as appropriate and marked with an approved label to correspond with the diagram of connections.

Glands exposed to weathering shall be totally wrapped in impregnated tape to exclude all moisture from the gland connection and have an outer wrapping of PVC tape.

403.1.12 Jointing

Personnel employed for jointing power cables including all types of terminations for aluminium conductors shall have received specialised training. Joints in all buried or stranded cables shall be sweated, but compression joints will be permitted for stranded copper or solid aluminium conductors at terminations only.

Joints shall be completed without pause or unnecessary delay. Reduction in the number of strands is not approved but limited reduction in the cross sectional area of solid conductors by an approved method is permitted. Cable cores shall be cut with due regard to fanned out terminations, leaving a neatly arranged minimum of slack core between cable and terminal. As far as practicable all H.V. joints shall be made to avoid crossed or twisted cores, final phasing out being arranged in the cable box termination.

Where a crossed joint is approved, a sleeve at least 30% longer than standard shall be used to minimise the distortion of cores. The Engineer shall witness the final termination in order that the Contractor may prove the phasing before the last joint in a cable run is made.

Cables shall be jointed colour to colour or number to number. Where numbered cores are to be jointed to existing coloured cores etc. the Engineer will direct the system to be used.

A reliable continuity path shall be provided for fault currents flowing via the lead sheath and/or armouring by means of an efficient earth bond between the cable armouring and sheath on each side of the joint.

Any semi-conducting screens incorporated in H.V. cables (i.e. XLPE rated at 6350/11000V) are to be thoroughly removed before the application of any stress control components supplied with the necessary cable jointing kits.

Where dissimilar cables are to be jointed eg. armoured cable to flexible cable of submersible pump, a junction box shall be employed.

Such box shall be arranged with suitable cable glands for incoming and outgoing cables and of a complete water and gas tight construction (IP67) using either cast iron or steel not less than 4 mm thick finished in accordance with Appendix A.

Internally a fixed two bolt termination block with termination for all cores and a removable link connection shall be provided.

A separate junction box shall be used for each through connection and shall be securely fixed to the structure in an accessible position.

403.1.13 Earthing and Bonding

All non-current-carrying metal parts of the electrical installation and other services shall be properly bonded together and connected by means of a protective conductor to an efficient earth in accordance with IEE Wiring Regulations.

All connections shall be by means of an approved mechanical joint or adjustable clamp which shall be accessible and made secure with brass nuts and bolts. On no account shall plain or spring washers of ferrous metal be used.

Protective conductors shall provide earth continuity either through the conduit, armouring, lead sheathing, copper sheathing, steel trunking or by independent earth tapes or PVC sheathed wires, according to the system of wiring employed. Where PVC conduits or trunking systems are employed the protective conductor shall be routed within the conduit or trunking.

Wherever cable armouring is used as a protective conductor, care must be taken to ensure an adequate earth bond and additional bonds to the metalwork shall be provided as required.

403.1.14 Main Earth Connections

Where a main earth bar is to be installed it shall be connected in a ring with the earth bar provided on the switchgear and any existing main earth ring in the building. The glands and wire armour of cables shall be connected to the switchgear earth bar or directly to the earth ring.

The main earth bar shall be formed from high conductivity, hard drawn copper bar Grade C101 to BS 1433 of not less than 31.5mm x 6.3mm cross-section. Any joints in the earth bar are to be brazed together using brazing alloy type CP1 to BS 1845 or pan head riveted and sweated. The bar overlap/thickness ratio shall be not less than 5.

The earth bar shall be secured to an inside wall in an accessible position. Connections to the metalwork of electrical plant shall be made in soft drawn copper tape or equivalent sized cables. Where plant is subject to vibration, connections shall be made using flexible conductors. All earthing conductors and equipotential bonding cables shall have a green and yellow PVC sheath, and earth bars shall have a green/yellow marker tape or sheathing applied.

Reinforced concrete or sheet steel piling shall be connected to the earthing system as directed by the Engineer. Structures of steel framed buildings shall be bonded to the main earth bars.

Earth rods are to be 16mm (5/8") diameter driven by an automatic hammer to a depth of approximately 4 metres. Spacing between rods is not to be less than the depth of the rod. Inspection pits shall be provided for each electrode to allow subsequent access for testing.

Where copper earth tape is buried below ground level it is to be served with PVC or double half lap wrapped with an approved grease-impregnated tape for a distance of at least 300mm above and below ground level.

The routing, dimensioning and arrangement of all main earth bars and connections shall be detailed on the schedules and drawings forming part of this Specification as called for in the Particular Specifications. Disconnecting links for testing purposes shall be provided as shown therein.

403.2 SELECTION OF CABLE RUNS AND SIZES

403.2.1 General

The route, arrangement and method of installation of all cables and the position of equipment and wiring points shall be marked out on site by the Contractor and agreed by the Engineer before any work is put in hand. Where cable routes and method of installation have been agreed, the Contractor shall be entirely responsible for measuring the lengths and cross section calculation of cables to be ordered and ensuring that the cables are supplied in the correct length and cross section. Cross section and length of cables shown on electrical schematics are only an approximation.

Straight through joints will not be permitted except where the route run is in excess of the maximum drum length, in which case the Engineer is to be notified.

Where necessary, protection shall be provided against mechanical damage.

Cables shall be free from kinks and the whole installation shall present a neat appearance.

Service installations for administration buildings, office, amenity buildings, etc. shall be carried out in full compliance with all local regulations.

When a cable is cut from a length on a drum the drum length shall be immediately sealed. All cables once cast and laid shall be terminated in their final position or effectively sealed. All cables shall be drawn from the top of its drum which shall be jacked and positioned from easy draw off in relation to its final position of installation. Where it is required for a long length of cable to be drawn from its drum, cable rollers or skid boards shall be used.

The general routing of cables shall be designed by the Contractor but the final routes shall be those agreed with the Engineer prior to any cable installation work being carried out. All cables shall be installed in strict accordance with the requirements of this specification.

403.2.2 Cables in Concrete Trenches

Where cables are run in concrete troughs or trenches, they shall be run on the floor of trenches less than 300mm deep. In trenches deeper than 300mm, cables shall be supported along the side of the trench on galvanised mild steel hangers, racking, cleats or on a suitable tray run supported from the side of the trench, whichever is specified. The spacing cleats or hangers shall be as specified under `Cable Cleats'.

Where use is made of existing trenches with existing cables installed, it may be necessary to reposition certain existing cables so that the new cables can be laid in a proper manner and the whole of the cables (new and old) left in an arrangement which is tidy and fulfils engineering requirements. Such repositioning work shall be carried out to the directions of the Engineer.

403.2.3 Cables on Trays or Ladders

Cables shall be laid flat and straight, properly dressed into position and fastened by cable ties or straps of metal reinforced PVC strip material, secured at intervals not greater than 1m for horizontal and vertical runs. Where the run is horizontal but arranged in the vertical plane, support spacing shall be as specified under `Cable Cleats'. Care shall be taken to space the cables to allow adequate cooling. Not more than seven cables shall be embraced by one group tie and not more than two layers of cables shall be run on one tray.

403.2.4 Cables in Ducts

403.2.4.1 General

Before drawing any cables in ducts, the Contractor shall ensure that they are clean and free from obstructions.

Adequately spaced temporary supports and cable rollers shall be provided for the drawing in of cables such that abnormal strains and damage to the cable is prevented; approved lubricants shall be used as necessary. Cable stockings shall be used for general drawing work, core pulling eyes being specially fitted for heavy hauls.

Stresses shall not exceed:	$10MN/m^2$ (1500 lb/sq in) on the lead sheath
	$70MN/m^2$ (10,000 lb/sq in) on the core

Maximum pulling tension shall not exceed 20 kN (4500 lb).

403.2.4.2 Duct Seals and Cable Transits

After the cables are drawn in, the Contractor shall seal the ends of all ducts, pipes or trenches leading into buildings, passing through walls or floors within buildings or underground chambers containing equipment for cabling associated with this Contract, whether occupied or not.

All cables, conduits or pipes shall be sealed into the ducts by means of a secure and effective water, gas, vermin and fire-proof material which will accommodate settlement and vibration. This may be a self-supporting non-setting mastic packed into the annulus to a depth at least equal to the sleeve diameter, or approved multi-cable transit units with appropriate fillers and insert blocks. All steelworks on such transit assemblies and frames shall be hot dip galvanised.

Where shown on the Specification drawings, transit frames will be incorporated in the construction by the Civil Works contractor.

403.2.5 Cable Laid in Ground

403.2.5.1 General

Where cables are laid direct in the ground, they shall be well bedded in fine soil or sand and shall be covered with protective tiles. A minimum of 60mm thickness of fine soil or sand shall be supplied around the cables. All cables running along any one portion of route shall be laid at the same time and no extra payment will be made for re-excavation should any cable be overlooked at the time of laying. The Contractor shall be responsible for all excavation, for the supply of fine soil or sand for bedding, and for the backfilling and reinstatement of cable trenches along previously agreed runs. Trenches shall not be back-filled until the installed cables have been inspected by the Engineer.

403.2.5.2 Clearance and Coverage for Buried Services

Where possible, electric cables and their ducts shall be routed so that subsequent excavation to expose another service will not disturb cables and electrical ducts. Where separated routes are not practicable then the following clearance shall be ensured.

Minimum Coverage

Type of Service	Vehicular Roadways	Open Ground or Footpaths
HV	1000mm	750mm
Others	750mm	500mm

Minimum Clearances

Type of Cable	To HV Cable	To LV Cable	To Other Cable	To Gas/Water etc Pipes
HV	150mm	300mm	300mm	300mm
LV	300mm	150mm	250mm	300mm
Others	300mm	250mm	150mm	300mm

The spacing of cables installed at the same time shall be generally in accordance with the above table, but where circumstances permit a more economical arrangement may be specified by the Engineer.

As far as possible electric cables shall avoid the same route as other services except where otherwise directed. Where such segregation is not possible then 50mm thick concrete or stone slabs may be used as separators with the Engineer's approval. Electric cables shall be at least 50 mm clear of the side of trench excavation. Adequate slack shall be left at each bend for cables laid direct.

403.2.5.3 Protective Cover Tiles

These shall be of the concrete apex pattern engraved `Danger -Electricity' or similar, of dimensions appropriate to protect the number of cables along a particular route.

Following the installation and compaction of the bedding soil or sand over the cable, covers shall be laid by the Contractor so that they overlap by approximately 30mm each side of the cable run. Where cables are displaced by no more than 300mm vertically, covers shall be installed only over the upper cable run.

403.2.5.4 Route Markers

These shall be of reinforced concrete with the words 'ELECTRIC CABLES' cast in one face. They shall either be of the flush block type approximately 300mm x 300mm x 150mm or the pillar type approximately 600mm high erected with 300mm projecting above the ground, as directed by the Engineer.

As soon as site conditions allow, the location of each group of buried cables and every joint shall be accurately marked. Concrete marker posts or blocks shall be set at the origin, changes of direction, joints and otherwise at intervals of 20 metres or as directed by the Engineer.

403.2.5.5 Cable Identification

Identification labels of durable corrosion resistant material shall be provided suitable for permanently affixing to the cable sheath by means of buckle type straps and shall carry the cable reference in PVC channel strip. The reference character sizes shall be not less than 4mm (5/32") high (Critchley Unilabel or similar).

Cable identification labels shall be fitted to each cable end below its respective cable gland, also where the cable passes through ducts or trenches and at each entry and exit to a room or building.

403.2.6 Cables in trunks

403.2.6.1 General

All trunking, bends, cover plates, tees, flanges, supports, fixings, etc. shall comprise an approved complete system capable of adaptation and erection without size modification and with compatible manufactured bends and accessories being used as far as practicable. The trunking access covers shall comprise easily removable convenient sized lengths retained over the entire length by clip-on features or suitable fastenings which shall not obstruct cable entries. Overlapping covers and internal flanges or coupling sleeves shall be provided at all trunking junctions. All cable supports, edges, sharp internal angles etc. shall be protected with PVC or formed to present a smooth edge.

403.2.6.2 Trunking Materials

i) Metal trunkings and fittings shall be zinc coated or galvanised mild steel not less than 1.2mm thick (18 SWG). Copper earth bonding straps shall be fitted at the junction of adjacent lengths of trunking and fittings.

ii) PVC trunkings and fittings shall be of high impact heavy duty rigid PVC.

403.2.6.3 Trunking Installation

As far as practicable, trunking shall be installed clear of other services and positioned so that future access is not restricted. Drawings detailing supports, terminations, sizes and centre lines of trunking shall be submitted to the Engineer for approval prior to commencement of the installation. Provision for expansion of the trunking materials shall be made in accordance with the manufacturer's instructions. Trunking shall include fire barriers of fibreglass wadding fitted at each point where the run passes through fire walls and floor levels. All cable and conduit exits shall be fitted with bushes without decreasing the effective cross-sectional area of the trunking.

When connecting adjacent sections of trunking or when fixing trunking to a wall or supports, round or mushroom headed bolts or screws shall be used such that no sharp edges project into the inside surface. When installed in damp situations the trunking shall be spaced from the wall by means of short tube collars.

All trunking shall be protected against damp and corrosion and where entries, joints and/or bends have been installed, cut and/or sawn edges exist, all damaged galvanising shall be made good by a minimum of two coats of primer (zinc based galvanised or similar approved equivalent) and two top coats of aluminium paint of an approved quality. For extensively damaged galvanised coatings the items shall be re-galvanised or replaced with acceptable components.

Conduit shall be connected to the trunking by means of couplings and male bushes to obtain a good earth connection.

To assist identification within trunking, final circuit wiring shall be formed into groups held by buckle clips or PVC straps. Each group shall be labelled where wiring enters or leaves the trunking and at intervals of approximately 15 metres in long trunking runs. In vertical runs the trunking shall be fitted with PVC coated pins at approximately 600mm centres to be used as cable supports.

Separate conductors comprising the same circuit shall be run enclosed together throughout their length.

403.2.7 Cables in Conduits

403.2.7.1 General

For wiring installations carried out with PVC insulated cables in conduit, the wiring throughout is to be on the "looping in" system and no "Tee" or other intermediate joint between fittings will be permitted, and in no case must the cable be drawn into the conduits until all such conduits, bends, boxes or other fittings have been fixed permanently in position and approved by the Engineer.

Any water which may accumulate in the conduit during erection shall be removed before any cables are drawn in. Sufficient slack shall be allowed at each point to ensure that all conductors are under no physical strain or tightness.

Separate conductors of the same circuit shall always be drawn into one conduit, but cables forming final circuits connected to different distribution boards shall not be drawn into the same conduit or box.
The cables shall be coloured RED or BLACK as required to distinguish opposite poles, a BLACK conductor shall be used throughout for neutrals and connected to the neutral pole of the supply system.

No reduction of the strands forming the conductors will be allowed at switch or other terminals; all the strands shall be efficiently secured by screws, nuts and washers or other approved means and all conductors shall be so proportioned that the drop of potential does not exceed that indicated by the IEE Wiring Regulations.

After the Contract award a Table (in duplicate) showing the proposed arrangement of wiring circuits and the size of cables to be used shall be submitted to the Engineer for his approval before any work is put in hand.

403.2.7.2 Conduit Materials

i) Metal All conduits and fittings shall be Class 4, galvanised steel, heavy gauge welded and screwed smooth bore tube employing threaded couplings and complying with BS 31 and BS 4568. As an exception, lengths of conduit completely encased in structural concrete may be finished with black enamel.

   Conduit boxes shall be of malleable cast iron. For surface work the lid shall be of cast iron machined or ground to make good contact with the boxes. Adaptable boxes for surface work shall be of malleable iron.

ii) PVC All conduits and fittings shall be heavy duty gauge PVC in accordance with BS 4607.

iii) Flexible Flexible conduits shall be waterproof metallic type PVC sheathed and adaptors to rigid conduit shall be of the internally rifled split brass type.

   Flexible conduit shall only be used for bridging expansion joints in a building or for final connections from the rigid conduit system to the terminal boxes of equipment subject to vibration or adjustment. All such conduit shall have an earth continuity conductor connected through the flexible adaptor at each end. Individual lengths of flexible conduit should not exceed 400mm.

403.2.7.3 Conduit Installations

The conduit system shall be continuous throughout so that the cables are fully protected. No conduit smaller than 20mm shall be used. Provision shall be made for draining condensed moisture where directed by the Engineer. The conduit throughout shall be of adequate capacity in accordance with the IEE Wiring Regulations, and shall be arranged with draw-in boxes to allow for easy draw in or out of any one or all of the cables in the conduit. For multiple parallel conduit runs, draw boxes may be combined by an appropriately sized adaptable box provided segregation of services is maintained.

Wherever possible, conduits shall be installed either horizontally or vertically and changes in direction shall be effected by easy bends or well formed sets without altering the section or opening joints; solid or inspection tees or elbows shall not be installed.

The inside surfaces of the conduit ends and all fittings shall be smooth and free from burrs and all other defects.

For surface work the conduits shall be fixed by means of spacer bar saddles or substantial distance saddles. Where conduits pass directly through concrete or similar floors and where washing down is likely to occur, the conduits shall be sleeved. The sleeve shall be grouted flush with the underside of the floor and extend 75mm above the top surface of the floor. Where conduits are run on steel work, they shall be fixed by means of purpose-made clips. If the Contractor requires to drill any steel work, permission in writing must be obtained from the Engineer.

In exterior situations, all joint box lids etc. shall be made waterproof with compound or gaskets as appropriate.

i) <u>Metal conduit</u> installations shall be electrically continuous throughout, and at all terminations conduits shall either be screwed into approved spigot boxes or coupled by means of screwed couplings and smooth bore hexagon bushes. In no case shall the length of the thread into which the conduit is screwed be less than the outside diameter of the conduit. Where tapped entries are provided and where internal space permits, a ring bush shall be used as a lock nut.

   All exposed threads and damaged galvanising shall be cleaned and thoroughly coated with zinc rich paint. If black enamel conduit has been approved for use, then where the black enamel is damaged the conduit shall be satisfactorily repainted to the approval of the Engineer.

   Contact between conduit and gas pipes shall be prevented wherever possible by adequate spacing, or by means of insulating distance pieces. Where the conduit is or may be in contact with any other pipes or metal work an efficient metallic connection shall be made between the conduit and the pipes or metal work and the incoming gas, water and electricity services shall also be bonded together, all as required by the IEE Wiring Regulations.

   Metal conduits shall be adequately grounnoud to BS7430.

ii) <u>PVC conduit</u> installations shall have couplers and spouted fittings joined with a permanent solvent adhesive, and provision shall be made in surface conduit installations for expansion by using a semi-permanent mastic jointing seal in expansion couplings as necessary.

   Conduits shall be fixed by means of spacer bar saddles spaced as defined in the IEE Wiring Regulations.

These figures apply to surface runs at normal room temperature. Where high ambient temperatures or rapid fluctuations are likely these spacings shall be reduced as agreed with the Engineer. Conduit shall also be secured 150mm either side of a bend.

The bending radius of PVC conduit shall be not less than 4 times the diameter of the conduit and bending shall be achieved by the use of the correct size bending spring. If bending is to be carried out in temperatures below normal room temperature, frictional heat shall be applied to the conduit before bending commences.

iii) Potentially Explosive Area conduit installations shall employ metal conduit and comply with the relevant Parts of BS 5345 for the specified zone classification; Ex(d) protection for Zone 1 and Ex(n) protection for Zone 2 applications.
All screwed joints whether entering into switchgear, junction boxes or couplings, must be secured by a standard lockout to ensure a tight and vibration-proof joint which will not slacken during the life of the installation and thus impair continuity and flameproofness. The length of thread on the conduit must be the same as the fitting plus sufficient for the locknut. Due to the exposed threads, the use of running joints is not permitted and specially designed flameproof unions shall be used for securing conduit to an internally screwed entry. All unwanted outlets shall be plugged with approved blanking plugs.

When a conduit passes from a hazardous to a safe area, the flameproof section must be terminated by a stopper box or sealing device mounted in the safe area.

All conduits entering directly into a flameproof enclosure where exposed terminals are fitted shall be sealed at the point of entry by means of stopper boxes which must be entirely filled with a non-oxidising compound. Conduit boxes or indirect entry compartments not containing exposed terminals do not require sealing.

Conduit stopper boxes of certified design must be used, having splayed, plugged filling spouts in the cover to facilitate the entire filling of the interior with compound.

403.3 CABLE MATERIALS

403.3.1 General

Cables shall be of approved design from a BASEC approved manufacturer having a certificate of Assessed Quality Management. They shall be manufactured within the 12 months prior to delivery and be delivered to site on cable drums or with protective wrappings.

The overall sheath of the cables shall be coloured as follows:

High Voltage	- Red
Low Voltage	- Black
Earth continuity conductor	- Green/Yellow or Green
Instrument	- Grey
Intrinsically safe	- Blue

Cables shall be of the voltage grade, conductor size and type detailed in the Particular Specifications. General specification of the cable type to be used are detailed hereunder.

i) Paper insulated mains cables shall be stranded plain annealed copper conductors, insulated with helically wound paper tape, mass-impregnated with non-draining insulating compound.

Multi-core cables shall be laid up in a belted construction having a lead sheathing applied overall, protected by a single wire armouring and having an extruded PVC sheathing overall (PLSW/PVC type).

Single core cables shall have a lead alloy sheath without armouring but with an extruded PVC sheathing overall (PLY/PVC type).

ii) Cross-linked polyethylene cables shall have stranded, copper conductors with cross-linked polyethylene insulation. Multi-core cables shall be laid up in an extruded bedding, single wire armoured and sheathed overall with PVC, to BS 5467 (XLPE/SWA/PVC type).

Single core cables shall have aluminium wire armour. Cables rated over 6350V shall incorporate graded semi-conducting tapes and core screens in accordance with IEC 502.

Low smoke and fume emission cables shall be as above except that the bedding and sheathing shall be of low smoke and fume emission material, all in accordance with BS 6724 (XLPE/SWA/LSF type).

iii) PVC armoured cables shall have stranded copper conductors with extruded PVC insulation, PVC sheathed, single wire armoured and sheathed overall with PVC (PVC/SWA/PVC type). Cables shall be in accordance with BS 6346. Conductors of 1.5mm² and 2.5mm² shall have stranded conductors (7/0.50 and 7/0.67 respectively).

iv) PVC insulated wiring cables shall be 450/750 volt grade single core stranded copper conductors PVC insulated to BS 6004 (PVC wiring type).

v) Mineral insulated cables conductors and sheaths shall be solid annealed high conductivity copper separated by highly compressed mineral insulating powder. The cable shall be sheathed overall with PVC.
Light duty rated up to 600V, heavy duty up to 1000V, all as BS6207 (MICS/PVC type).

vi) Telephone cables shall be thermoplastic insulated multipair cables having twisted pairs of copper conductors (telephone type).

vii) Instrumentation cables shall be polyethylene insulated copper conductors with twisted individual pairs screened, polyethylene bedded, steel wire armoured and PVC sheathed overall, all in accordance with BS 5308 Part 1 Type 2. Conductors shall be 0.5mm² stranded 16/0.2mm (PE/IS/SWA/PVC type).

viii) Earth and bonding cables shall have stranded copper conductors PVC insulated and sheathed (PVC/PVC type).

ix) Flexible cables shall have stranded, tinned copper, flexible conductors, EP rubber insulated and CSP sheathed all in accordance with BS 6007 (flexible type).

x) Flame retardant cables shall be EP rubber insulated, tinned copper conductors in a CSP sheath, braided with galvanised steel wire (single cores having phosphor bronze wire) and protected with a CSP sheath overall, generally in accordance with BS 6883.

The sheathing shall have heat and oil resisting characteristics to BS 6899 with an oxygen index value not less than 35 (HOFR type).

403.3.2 Mineral Insulated Cables

Cables shall be installed saddled to trays, run on the surface or as otherwise specified. The spacing of saddles shall be in accordance with the IEE Regulations. Cable termination accessories and saddles shall be brass or copper and shall be supplied by a particular cable manufacturer. All cables shall have a temporary mastic seal applied during installation. Once cut to length, each cable shall be permanently terminated without delay by using an approved seal. Termination seals shall be anchored in approved glands and locked into screwed conduit entries or gland plates forming part of accessories or equipment. Wherever possible, glands shall be locked in position with locknuts. Shrouds shall be fitted over glands except where they are encased in the structure of the building.

In cables where dampness may be present or where dissimilar metals are present, corrosion inhibiting paste shall be interposed in all voids between surfaces in contact.

Where MICS cable serves an inductive circuit liable to voltage surges or circuits subject to lightning surges, appropriate surge diverters shall be connected across the inductive sources (coil etc.) or between lines and earth at the point of entry in the case of lightning protection.

403.3.3 Single Core Cables

Circuits utilising single core cables shall be installed under IEE 'Defined Conditions' but to minimise mutually induced voltages, three phase circuits shall be run for as long as possible throughout the route in close trefoil formation. Where a circuit employs more than one cable per phase, each trefoil group shall contain one cable of each phase, allowing at least 50mm clearance between adjacent groups. Cleat spacing shall not exceed 1.2 metres.

Ferrous screens or armour shall not be used on such cables and associated terminations or enclosures must avoid the use of magnetic material which would provide a flux path in service.

To control induced voltages, single core cables shall have their metallic sheathing and/or aluminium armouring bonded together at both ends of the run, the bonding being connected directly to the system earth bar or other approved points. Cables having no insulating oversheath shall have their metallic sheaths or armouring bonded together by the use of normally spaced, well fitting, non-magnetic metallic trefoil cleats.

In all cases the bond shall be sized to carry the prospective fault current and have a conductivity not less than that of the cable sheath and/or armouring. Bonds for cables laid in a flat formation shall also allow for the unequal sheath currents.

To prevent circulating currents, bonding and earthing at the supply end only of short runs of single core cables will be permitted where it can be shown to the satisfaction of the Engineer that the induced voltages are safe under fault conditions.

403.4 CABLE ACCESSORIES

403.4.1 Compression Glands for Cables

All the glands shall be supplied by the Contractor and shall be of the brass compression pattern, so designed that any strain on the cable is taken by the steel wire armouring. The glands shall incorporate watertight seals on both inner and outer sheaths and have a separate armour clamping ring to ensure a good mechanical connection for the earth continuity path. The glands shall be secured with heavy duty locknuts and the whole assembly is to be protected by an overall plastic sleeve, suitably sealed to prevent atmospheric attack.

Glands fitted to unthreaded gland or adaptor plates, non-metallic equipment, or where specified for circuits likely to pass high fault currents, shall include a brass earthing tag and connections arranged to effectively bond the gland body via a protective conductor to an effective earth point. Where instrument cable screen terminations need to be isolated, insulated gland adaptors or non-metallic plates shall be used.

Glands and earthing tags shall be compatible with the gland plate and cable armouring materials to prevent electrolyte corrosion; eg. brass for steel wire armouring/gland plate and aluminium for aluminium wire armouring/gland plates.

Glands fitted in Zone 0 and 1 potentially explosive atmospheres shall be similar to those described above, but shall be classified Ex (d) in accordance with BS 5501 Pt 5 and be suitable for use with Apparatus Groups IIA and IIB.

Where cables to BS 6346, BS 6116 or BS 5467 having an extruded or taped bedding are used for direct entry into such apparatus Groups, a sealing stopper box or compound sealed barrier gland shall be used in accordance with BS 5345 Part 3.

403.4.2 Wiring Ferrules

These shall be of durable materials suitable for permanently affixing to the cable cores and be of the interlocking slide-on type, such that the interpretation of the reference is unambiguous.

All control circuits consisting of more than two wires shall be identified by means of wiring ferrules attached to the individual cores at each end of the conductor where it is connected to any apparatus or junction box.

Unless otherwise specified, it shall be the responsibility of the cabling contractor to obtain interconnection terminal data and references from the equipment manufacturer to enable proper connections to be made.

403.4.3 Cable Cleats

Cleats for fixing cables to walls, structures, etc. shall be of the non-corrodible hook and clamp type made of high impact plastic or cast aluminium comprising two halves fixed by means of galvanised rawlbolts or on to galvanised backstraps where the number of cleats makes this more economic.

All assemblies to be complete with necessary galvanised bolt, nut and washers.

The spacings of supports or cleats for cables shall in any case be not greater than shown in the following table but, where circumstances merit, closer spacing arrangements may be required by the Engineer.

The vertical spacings shall be applied to runs sloping up to 30° from the vertical. For greater deviations, the spacing for horizontal runs shall apply.

For outdoor and damp situations, fixing bolts or studs for cleats shall not be less than 13mm overall diameter unless otherwise agreed by the Engineer.

Cable Support Spacing (mm)

Cable Type	XLPE/SWA/PVC or PVC/SWA/PVC with stranded copper conductors	
Overall dia (mm)	Horizontal	Vertical
up to 15	350	450
15 - 20	400	550
21 - 40	450	600
41 - 60	700	900
over 60	1100	1300

403.4.4 Cable Racks

Cable racks shall be robustly constructed of mild steel, not less than 2.5mm (12 SWG) in thickness and galvanised after manufacture. Where cleats are not used, the rack shall be provided with a toe at the outer end. Racks of proprietary construction may be used subject to approval.

Main rack supports, where fixed to brickwork or concrete, shall be secured with bolts of not less than 13mm diameter. The fixing bolts shall be of the self-securing type with expanding sockets and shall not require grout to hold them in position.

Where fixed to walls in places subject to dampness and in cable subways, the racks shall be set off from the walls by 35mm x 18mm thick galvanised packers placed at the bolt fixing positions.

In cable basements, the lower tier of any row of racks etc. shall be not less than 100mm above finished floor level.

403.4.5 Cable Ladders

Cable ladder shall be heavy duty type, fabricated from mild steel not less than 2mm thick and galvanised after manufacture. The side rails shall be at least 120mm deep with rungs set towards one edge, spaced at regular intervals of approximately 300mm and having elongated slots to accommodate the cable fixings.

Lengths of ladder shall be coupled and changes in direction, level and width shall be achieved by means of standard accessories designed for the system, such as radiussed risers and gusseted intersections. Cable tray shall be accommodated on the ladder system for cables less than 15mm overall diameter.

403.4.6 Cable Channels

Cables requiring mechanical support across voids may be accommodated in not less than 40mm square galvanised channel sections fitted with plastic closure strips and suitable end caps in preference to tray, and subject to the Engineer's approval.

403.4.7 Cable Trays & Covers

The Supplier shall supply and erect all required cable traywork.

The following points are to be taken into account selecting routes for cable trays : -

i- Number of drive, power and control cables to be located on each cable tray.

ii- The avoidance of pipework and pipework required for future extensions.

iii- The avoidance of maintenance areas of machinery, pipes, etc.

iv- The avoidance of installation areas for the future extensions to the plant.

v- The avoidance of unnecessarily long runs of cable.

Cable tray shall be heavy duty pattern formed from galvanised sheet steel, perforated with elongated holes for cable fastenings and shall have suitable covers made of identical material and thickness. The tray shall have side flanges not less than 25mm deep with returned edges and be galvanised after fabrication. Material gauge shall be 1.5mm (16 SWG) minimum, except that for tray widths less than 400mm the gauge may be reduced subject to the flange depth and the approval of the Engineer. Factory made tee sections and bends shall be used where possible.

The cutting of trays shall be kept to a minimum but where unavoidable, all cut edges shall be rounded or folded over and protected with zinc rich cold galvanising paint, holes for cables shall be bushed with nylon/PVC strip edging material. Mushroom headed bolts and nuts shall be used to join sections of tray and accessories and arranged not to present any obstruction on the tray. Capacity amounting to 25% usable tray area shall be left spare.

Where specified herein for damp or corrosive conditions, the trays shall be of unplasticised PVC with non-corrodible nuts and bolts.

Metal cable trays shall be adequately grounded to BS 7430.

403.4.8 Sealing Boxes for Lead Sheathed Cables

For terminations at plant items, these will be provided by others except as specified herein and will be of cast iron, compound filling type, provided with filling plugs in the appropriate position for filling with compound when mounted on the associated equipment. Each will be complete with wiping cone armour clamp. For through joints or tee joints, the Contractor shall provide suitable boxes as detailed herein.

All necessary jointing materials, filling compounds and earthing requirements shall be included for all joints to be made under this Specification.

403.4.9 Sealing Compound

The outer protection boxes for joints or terminations shall be filled with compound of the hot or cold pouring variety of a type compatible with the cable materials to be agreed by the Engineer.

Compounds which require heating shall be evenly heated, well stirred and the temperature maintained within the recommended pouring ranges. Cable accessories shall be thoroughly dried before filling and pre-warmed where possible.

Where cable sealing boxes are fitted beneath oil-filled compartments or where inverted cable sealing boxes are used due to cables entering from overhead, the compound shall be of the oil resisting type to prevent any risk of softening due to contamination from the insulating oil.

Cold pouring resin encapsulation materials shall be carefully mixed to avoid entrapped voids or uncured filler materials.

403.4.10 Busducts

Connections between major electrical items shall (where specified) employ a fully integrated, totally enclosed, busduct system to BS 5486 (IEC 439-2), comprising HDHC copper conductors embedded in a non-flammable, self extinguishing, cast epoxy resin insulation.

The complete assembly including junctions shall be completely free of condensation and watertight to IP68. Fire resistance shall be Class M1 (F) and Class B1 (D) to IEC 332.

All parts of the system shall be from the same manufacturer and comprise factory made lengths, bends, tees and terminating pieces to suit the physical application and layout of the installation.

The voltage and prospective fault ratings of the system shall be suitable for the application and the current rating shall be based on the most onerous method of installation for the circuit. The cross sectional area of the conductors shall not be reduced throughout a given circuit.

The installation shall allow for any necessary expansion, be properly supported and connected in accordance with the manufacturer's instructions. Fire and damp-proof barriers shall be provided when passing through walls, floors/ceilings etc.

Conductors shall be jointed by means of double junction plates, one on each side to ensure low joint resistance. The junction shall be compressed by means of high tensile steel nuts and bolts. After assembly, all junctions shall be overcast with the same materials mixed under vacuum, as used for the busduct elements, thus maintaining a homogenous and weatherproof enclosure throughout.

Provision for conductor shifting, transfers and paralleling, shall be made within the terminal elements.

404. CIVIL WORKS FOR CABLE INSTALLATIONS

404.1 GENERAL

The works involved are associated with the cable installation and comprise trenching, excavation, supply, laying and jointing of cable ducts; building of jointing and draw-in pits; application of bedding sand or soil; temporary reinstatement of ground. The installation of cables, supply and laying of cable covers and preparation of route record drawings will be carried out by the contractor appointed to undertake the cable installation. Excavation, duct and cable laying and backfilling shall proceed in accordance with an agreed program ensuring that all cables and ducts are satisfactorily covered immediately following laying and after approval from the Engineer.

404.2 TRENCHING MEASUREMENTS

The depths and widths of individual trenches for cables or ducts and the clearances from other services shall be determined by reference to the clauses in this part. For contracts let with scheduled rates it will be assumed upon re-measuring that excavations have been in accordance with this specification unless the Engineer has been sent an advice to the contrary.

404.3 COVERAGE FOR BURIED CABLES OR DUCTS

Trenches shall be excavated or ducts laid at such a depth that the minimum coverage to the top of the duct or the cable shall comply with the following:

Type of Service	Vehicular Roadways	Open Ground or Footpaths
HV	1000mm	750mm
Others	750mm	500mm

404.4 CLEARANCES BETWEEN OTHER SERVICES

Where possible electric cables and their ducts shall be routed such that subsequent excavation to expose another service will not disturb cables and electrical ducts. Where separate routes are not practicable then the following clearances shall be ensured:

Type of Cable	To HV Cable	To LV Cable	To Other Cable	To Gas/Water etc Pipes
HV	150mm	300mm	300mm	300mm
LV	300mm	150mm	250mm	300mm
Others	300mm	250mm	150mm	300mm

Where such spacings are not possible then 50mm thick concrete or stone slabs may be used as separators with the Engineer's approval. Each cable shall be at least 50mm clear of the side of the trench excavation.

404.5 EXCAVATIONS AND PRECAUTIONS

Turf and topsoil shall be carefully removed and positioned where indicated on the drawings or as directed by the Engineer for subsequent reinstatement in their original position.

Broken land drains and damage to other services shall be reported to the Engineer and marked on site.

Excavations shall be kept free of water and properly shored up. Other services uncovered shall be adequately supported by slings or other means and protected.

404.6 BEDDING FOR CABLES

Prior to laying the bedding for the cable, the bottom of the trench shall be cleared of loose and projecting rubble etc. and evenly graded.

A sand bedding shall be applied below and around the cables and shall be thoroughly compacted. Thickness of bedding around the cable shall be 60mm except where soil contains coke, ash or other corrosive matter where the thickness shall be 200mm. Bedding shall be well graded sand, free of clay with minimum particle size of approximately 0.08mm (BS sieve No. 200) and maximum particle size of approximately 2mm (BS sieve No. 7). 60% of the material shall pass through BS sieve No. 72. Where the Engineer directs, local soil may be used for bedding after passing through a 10mm mesh sieve provided the material is evenly graded.

404.7 DUCTS AND COUPLINGS

Buried cable ducting shall be smooth bore UPVC pipe to BS 4660 (or medium density polyethylene, where greater flexibility is required) jointed by spigotted ends or couplings of compatible, non-deteriorating material. These couplings shall be a self-aligning, push fit and incorporate seals to prevent the ingress of water and other fluids as far as possible and the joint so formed shall be equal in internal diameter to the duct itself.

Ducts entering below ground level into a building or structure shall emerge inside the building either directly into an accessible trench or void, or the duct shall have an upturned bend to emerge adjacent to an inside wall face, or as otherwise specified.

All exposed upturned duct ends shall project at least 75 mm clear of the finished floor or ground level to prevent unwanted collection of water or debris and protect the cable exit.

404.8 BEDDING OF DUCTS

Prior to laying ducts in trenches, the trench bottom shall be evenly graded, cleaned of loose rubble etc. and compacted to form a solid foundation. In rocky soil a layer of loose, rock-free earth shall be used for this foundation.

Where ducts are laid beneath vehicular access roads, the ducts shall be haunched in C20 concrete for the full width of the road and extend each side beyond the curbside by at least 300mm.

404.9 DUCT ALIGNMENT AND CLEANING

Ducts shall be laid in a straight line as far as possible with minimum deviation. Where bends are required, these may be manufactured, pre-formed bends with a radius of not less than 10 times the bore diameter. No continuous duct run shall incorporate more than two bends nor turn through a total of more than 135° in any plane. No single bend shall exceed 90°.

Where greater changes of direction are necessary, cable draw pits shall be incorporated in the run as required or defined by the Engineer.

A non-corrodible draw wire or rope shall be left in each duct and plugs shall be inserted at the ends of each section of duct to prevent entry of soil or stones. On completion of the ducts and prior to drawing in cables, a circular wire brush 6mm greater in diameter than the duct shall be pulled through each duct.

404.10 CABLE DRAW PITS

Cable draw pits shall be of reinforced concrete construction fitted with suitable removable access covers and have bellmouthed duct entries into the pit interior. The interior dimensions shall be determined by the Engineer but shall be not less than 750 x 600mm for power cables and not less than 600x600mm for telemetry cables in plan, the depth shall be determined by the invert level of the lowest duct with a minimum of 150mm clearance to the base of the pit.

Where specified, a pulling eye for the use of a 2000kg pulley block shall be provided opposite each group of ducts in the wall of the pits, and positioned to facilitate as straight a pull as possible on the cables with the use of a pulley block. The base of the pit shall be formed with a fall towards a sump, suitably placed for pumping dry.

404.11 BACKFILLING AND REINSTATEMENT

Reinstatement of soil following laying of cable or duct shall be effected by backfilling in 100mm layers. Hand ramming shall be employed for the first two layers and power ramming for subsequent layers. Backfilling shall only proceed in the presence of the contractor responsible for laying cables.

After hand ramming to a depth of 200mm, a yellow coloured plastic tape approximately 150mm wide with the words `CAUTION ELECTRIC CABLE BELOW' shall be provided and run over the centre of the route of each cable run.

Top soil is to be replaced and the level of the finished reinstatement shall not protrude more than 50mm above ground level. All surplus spoil is to be removed from the site, and areas surrounding the excavation shall be restored to their original condition. Where tarmac surfaces have been excavated, the final 200 mm backfilling after allowing the settlement shall consist of 120 mm of compacted graded hardcore, followed by 60 mm concrete screed and a 20 mm top dressing of tarmacadam.

404.12 CABLE TRENCHES

Trenches cast in floors or ground shall be of specified internal dimensions to suit the specific installation. They shall have smooth vertical sides and bottom with provision for cover plates to finish flush with the finished floor surface.

Inside bends shall be either radiussed (150mm min) or chamfered at least 100mm back, equally angled from each direction. Such radiussing or chamfers shall extend the full height of the trench, however the top 100mm may be corbelled out to simplify the cover plate arrangement.

Trench covers shall be of aluminium or galvanised mild steel chequer plate (min 8mm thick) supported to prevent undue flexing and having suitable holes to allow removal by standard lifting keys. Support shall be by means of steel curbing rebates cast into the trench top edges, providing a landing width of at least 30mm.

Additional or alternative support for switchboards etc shall be from at least 75 x 35 mm channel section cross bearers and transverse trimmers, fixed or cast into the floor and located to suit equipment fixings, access requirements and floor cover spans.

To prevent differential deflection, butt straps shall be fitted to the underside of floor plates which have no other support.

Edging curbs suitable for mild steel chequer plate shall be painted in red oxide primer, the curbing may be tapped to accept cover securing screws. Where aluminium plates are used in contact with any mild steel supports, a bitumen coating on the points of contact shall be used.

404.13 CABLE TROUGHS

Pre-cast concrete trough sections shall be laid either flush or upon the finished ground level as specified.

The sections shall be sized and provided with rebated covers to suit the span and any imposed load conditions specified, eg. at road crossings. Provision shall be allowed for handling/removal of such covers. Pre-formed junctions and turn-outs shall be provided with suitable chamfers on inside bends.

404.14 TRANSFORMER BAYS

The dimensions and weight of the transformers are specified herein in order that access clearances and loadings may be determined. The transformer bases shall be located at ground level, accessible from a made up road or hard standing to the bays.

Each transformer bay shall be separately enclosed to prevent unauthorised access and be partitioned by plain brick blast walls up to a height of 2.2m, with one side being fitted with full width, lockable open-mesh gates or louvred doors for access and ventilation. Where roof covering is necessary, it shall be of non-flammable construction and allow 800mm clearance at least for natural ventilation of the transformer.

The bay shall be sized at least 1.5m greater than the transformer width (across terminal boxes) and at least 1.0m greater than the transformer depth. A level concrete mounting ramp shall be located within the bay area suitable for rolling the transformer into position, and a pulling eye shall be fitted centrally in the rear wall at ground level.

The area surrounding the plinth within the bay, and enclosed after transformer installation by a low bund wall if required, shall be excavated sufficient to accommodate 10% in excess of the transformer oil capacity when filled with fire quenching 50mm graded pebbles having 30% voids. Provision shall be made for drainage of accumulated rainwater.

Cable ducts shall be arranged to suit the cable routes and have up-turned spouts projecting clear of the designed oil/pebble level for the bund.

Alternatively, provision shall be made for the oil to be conducted to underground drainage tanks having access for pumping out, separate tanks being provided for each transformer.

For silicon cooled transformers of sealed construction, quenching pebbles will not be required, but an oil catchment area shall be provided where specified.

404.15 EARTHING CONNECTIONS

Two earthing connection tabs shall be welded to the concrete reinforcing bars in the positions shown on the specification drawings and be incorporated in the concrete encased, reinforcing steel network of the building foundations. The network shall be not less than 30m in length, buried at least 1m below ground level. The total length may comprise more than one bar, welded together to form the required minimum length.

Each earthing tab shall be of hot dip galvanised flat bar steel 50mm wide x 6mm thick, attached by welding to at least two parallel reinforcing bars (9mm diameter minimum) and of sufficient length to project beyond the finished concrete surface by at least 100mm in an accessible position.

The welding shall be of good mechanical strength over the full 50mm tab width and shall be located in an area of the rebar not required to provide structural strength, such as a trimmer or surplus length of the bar.

The reinforcing steel of existing buildings may be used to provide the electrode for a new installation or to replace a damaged or deficient conventional earthing system. A substantial rebar of a main beam or column shall be exposed by chipping away its concrete cover. The earthing terminal plate shall be welded to the rebar and the removed concrete replaced by mortar.

405. ROAD LIGHTING

405.1 LUMINAIRES

The Luminaires shall be weatherproof to at least IP 55 or as otherwise specified. The output and spectral distribution characteristics shall be as detailed in the Particular Specifications.

405.2 CONTROL GEAR

The Control gear for the lamps shall be mounted in the lantern head or base of the column as appropriate. The circuit components shall be suitable for the range of temperatures and humidity as defined in BS 4533. Power factor correction capacitors shall be included to give an overall improvement to at least 0.85.

405.3 CONNECTION COMPARTMENT

A connection compartment shall be provided and have a flush fitting, vandal proof door with a weather skirted cover to IP 55, secured by two key headed non-corrodible latches. A non-corrodible earth terminal and non-hygroscopic back board shall be provided within the compartment.

The column shall be set such that the compartment door is fully accessible and faced away from the adjacent traffic stream.

The connection compartment shall also incorporate a bekable disconnect switch for power isolation.

405.4 COLUMNS

Columns shall be suitable for the specified duty and be manufactured and installed in accordance with requirements of BS 5649 (EN 40). They shall be made of hot dipped galvanised mild steel, aluminium or pre-stressed spun concrete with tubular tapering or multi-sectional construction without the use of welds or swaging and having an internal cable way throughout the length.

The head of the column shall have a 76mm dia spigot extension or other means of accepting the lantern head or bracket. The head shall also incorporate an anti-rotation device to fix the arm at 90° increments to the door.

The column base shall be either a substantial surface mounting plate to BS 5649 or rooted for securely supporting the whole column on/in the ground in a vertical position. Rooted columns shall have a side exit port 500mm below ground level for cable access and be planted at depths related to column height as specified in BS 5649.

The base and root section of steel columns shall have a minimum nominal material thickness of 5mm.

The columns shall be installed in accordance with the manufacturers recommendations and concrete foundations shall be to grade C20 with a maximum aggregate size of 30mm.

405.5 LOCATION OF LUMINAIRES

The position of all luminaire/columns shall be as indicated on the Engineers drawings and as agreed with the Engineer. These positions shall be clearly marked on site to prevent obliteration before the work is started.

405.6 EXCAVATIONS

Holes shall be excavated to the appropriate column-planting depth, unless the excavations are in hard material or loose sand, when any necessary alterations in planting depth shall be the subject of agreement with the Engineer. The width of the holes shall be kept to a minimum compatible with the conditions encountered under the surface and the surrounding soil shall be disturbed as little as possible. The width of holes in loose soil or sand may require to be greater to allow for heavier foundations and the dimensions should be agreed with the Engineer. In normal well-consolidated soil, the width of the holes should not greatly exceed the width of the base plates or flags where these are used. The maximum width of flags placed under the base of concrete columns should normally be limited to about twice the width of the column base.

During excavation, every care shall be taken to avoid damage to underground services or other property and any paving flags shall be lifted carefully and preserved for disposal as directed by the Engineer.

Agreement shall be reached with the Engineer on the method to be used for excavating rock or other hard material. Explosives shall not be used except with the express approval of the Engineer.

Excavations shall be lighted and guarded in accordance with local bye-laws, safety codes and regulations including CDR Safety Requirements, as applicable to the site.

Where underground obstructions are likely to necessitate the use of columns with special roots or re-sitting of the column positions, trial holes should be taken out at each position or at selected positions as decided by the Engineer.

405.7 ERECTION OF COLUMNS

Before erecting columns in position the excavation shall be examined to see that it is clear of obstructions and the foot firm and free from water, rubble or loose soil; the roots of steel columns shall be examined to ensure that the priming coats are complete. Any bare or corroded patches shall be cleaned and treated with black bituminous paint, unless it is specified that these should be left untreated for earthing purposes.

Base plates, where provided, shall be fitted securely, and where used for earthing purposes shall be electrically bonded and base stones or flags shall be placed in position where appropriate.

Any precautions necessary for the warning of traffic during erection shall be taken and any rope slings shall be visually examined before and after each lift to ensure that no deterioration has taken place.

405.8 ALIGNMENT

Columns shall be correctly aligned in the vertical position or at the rake agreed by the Engineer. The cable hole for the bracket shall be in the correct position relative to the road so that the bracket, when fixed in its correct position, will align correctly with the cable hole. Unless otherwise specified, the door opening shall face away from oncoming traffic.

405.9 BACKFILLING

When the columns have been placed in position, the holes shall be filled in and well consolidated.

(a) **Group A Installations**.

Excavations for Group A installations shall be filled in with enough concrete to hold the columns firmly in their true position. Unless otherwise specified, the concrete shall be brought up to within 450mm of the ground surface. The concrete shall be efficiently mixed so that there is a uniform distribution of material and the mass is uniform in colour. Concrete shall normally be placed in position before the initial set has taken place ie. 1½ hours after mixing has been completed, but in any event within such a time that it can be consolidated effectively without the addition of further water. The concrete shall then be thoroughly tamped and compacted by hand or by other satisfactory means, at intervals of not more than 150mm, at the same time ensuring that the column does not depart from its correct setting or alignment.

(b) **Group B Installations**.

Excavations for Group B installations shall be filled in with selected excavated materials, concrete or other materials to the satisfaction of the Engineer.

Adequate provision shall be made for the entry of underground services to the columns.

405.10 TEMPORARY REINSTATEMENT

The remainder of the hole shall be filled with soil which shall be well rammed at regular intervals. The finished level shall be substantially the same as that of the surrounding level.

The earth around the column shall not be disturbed for at least seven days after temporary reinstatement.

405.11 TREATMENT OF COLUMNS AFTER ERECTION

(a) **Concrete Columns**.
The joints between parts of concrete columns shall be pointed in accordance with the manufacturer's instructions. The colour of the material used shall match the colour of the columns.

(b*)* **Steel Columns**.
The exterior surface and external metal attachments of metal columns shall be painted after erection in accordance with the specification.

405.12 MARKING

After erection, columns shall be clearly marked with painted numerals, number plates or separate characters firmly secured to the columns, as specified by the Engineer.

405.13 ELECTRICAL EQUIPMENT

Lanterns, switches, control gear and accessories shall be fitted, wired and connected in accordance with the IEE Wiring Regulations for Electrical Installations and the work shall be done by a qualified electrician.

Fuse cut out boxes shall be made of flame retardant, resin moulded materials incorporating fuseways, looping terminals and earthing connections to suit the application. Fuse covers and other access to live parts shall be accessible only by the use of tools.

Metal columns, lanterns and the external metal work of switches and control equipment shall be electrically bonded, to the satisfaction of the Local Electricity Authority, and unless otherwise specified, connected to earth by one of the following methods:-

(i) In installations served by an underground supply, by a conductor connected to the metal sheath of the supply cable (the bonding of this connection to the cable sheath is normally the responsibility of the Local Electricity Authority).

(ii) In any section of an installation served by an overhead wiring system, if a continuous earth wire is available along the entire length of the system, by a conductor suitable for connection to this wire; if no continuous earth wire is available, by individual earthing to each column in a manner to be specified by the Engineer.

Lanterns shall be attached to the columns only after the columns have been securely fixed in their agreed vertical and horizontal alignment. Together with any optical components, they shall be correctly orientated with the road in accordance with the manufacturer's instructions. Leveling devices shall be used as supplied and as recommended by the manufacturer.

The lamps shall be carefully inserted in the lanterns without subjecting them to undue mechanical shock or vibration. Care shall be taken to ensure that lamps operate in the correct burning position, in accordance with the lamp manufacturer's instructions. Lamps, reflectors, bowls and refractors shall be clean and free from dust or obscuring films after assembly.

405.14 WALL AND BRACKET MOUNTING

In the absence of detailed instructions, the erector shall ensure that wall brackets and wall-mounted lanterns are securely fixed to structurally-sound parts of the wall. The dimensions of fixing screws and wall plugs should be adequate for the loads to be carried. Where lanterns are mounted on long outreach brackets or where large surface areas are involved, the lanterns or brackets should be fixed to solid brick or stone walls by means of thoroughly caulked or grouted rag-bolts of adequate dimensions. The method of attachment to timbered buildings or other forms of construction should be the subject of agreement with the Engineer.

Control gear not located inside the lantern should be housed in robust waterproof and tamperproof containers, securely fixed to the wall if appropriate. Surface wiring between the lantern and control gear compartments should be protected mechanically by means of heavy gauge welded steel conduit or steel wire armoured cables.

The requirements of the statutory authority should be complied with where street lighting lanterns and accessories are mounted on poles owned by statutory authorities.

405.15 FOLDING COLUMNS

Where folding columns are specified for maintenance access, the two sections shall be positively seated and hinged to prevent unauthorised interference. The extended skirt shall totally enclose the gear compartment to provide protection to IP33. The upper section may only be lowered by use of a specially designed device to assist the operation. At least one lowering device shall be provided together with one additional device for every multiple of one hundred such columns installed.

405.16 FEEDER PILLARS

Feeder pillars to accommodate electrical distribution components shall be made of cast iron, sheet steel, aluminium or glass resin bonded polyester material as specified in the Particular Specifications.

They shall be free standing assemblies, designed for base mounting either direct to concrete plinths or for attachment to separate root extensions suitable for direct burial. The shell shall be partially removable to allow access for cable jointing and termination.

Doors shall be hinged with stainless steel pins in nylon bushes and allow 180° opening. They shall sealed all round with a watertight gasket and be secured by wedge type locks, protected by brass cover plugs requiring special keys to prevent unauthorised access.

The housing shall incorporate baffled ventilation apertures to provide overall enclosure protection to IP 34. Equipment mounting boards within the pillar shall be of non-hygroscopic material.

405.17 HIGH MASTS

The masts shall be manufactured from mild steel to a tapered profile using the minimum number of horizontal joints. The base flange shall be adequately welded and gusseted and the base compartment opening shall be reinforced to maintain the strength of the mast.

The mast head frame and lantern carriage shall be a welded steel construction, hot dip galvanised after assembly. The head frame shall be protected overall by an aluminium canopy and the lantern carriage shall be designed to enable it to be assembled or removed from the column after erection. Guides shall be provided to ensure the carriage engages securely into the head frame.

The carriage mounted junction box shall house the connections to the lanterns and the electrical supply cable. The cable shall be a flexible multicore with EPR insulation and sheathed with heavy duty PCP. Electrical disconnection by means of a plug and socket with a threaded coupling facility shall be provided in the base of the mast. A similar electrical coupling shall be provided at the lantern carriage to enable the supply to be directly connected to the lantern when the carriage is at ground level.

405.18 WINCHING ARRANGEMENTS

Manually operated or power driven winches shall be provided where specified for raising and lowering Luminaires or lantern assemblies. They shall incorporate an automatic gravity latch and a disc brake on the drive shaft to prevent creepage when the winch is stationary. Lifting ropes shall be formed of flexible stainless steel strands and sized to operate within their rates safe working load with a safety factor of 5 : 1.

Winches shall be driven through a worm reduction gearbox, totally enclosed in a cast iron gear case filled with lubricant for life. Power drives for the gearboxes shall be transferable and coupled through a mobile mounting jig as required.

On high masts, multiple ropes shall be used and arranged to maintain a level rise and fall. The pulleys for the hoist ropes and the electrical supply cable shall be of cast aluminium and shall have close fitting guides to ensure correct location of the ropes and cables during operation. The electrical cable shall also have guide rollers to assist centring.

The fixed and moving elements of Luminaires designed for raising and lowering by means of winching shall incorporate guidance channels and latching mechanisms to ensure secure engagement and release in conjunction with the winching device.

406. ELECTRICAL INSTALLATION FOR BUILDINGS

406.1 GENERAL

Electrical installations for buildings shall comply with the French Standards as normally applicable in Lebanon.

Materials and works for building electrical installations shall comply with:

- D.T.U. (Unified Technical Document) No. 70.1 published in December 1971 and completed by erratum July 1981
- D.T.U. published in April 1973
- N.F.C. 15-100: Electrical installations
- N.F.C. 71-800: Security blocks
- N.F.C. 13-200: High voltage electrical installations - Regulations
- N.F.C. 14-100: Sub-circuits installations - Regulations
- N.F.C. 15-150: High voltage gas discharge lamps installations

The works which are the subject of this specification are for the installation of the electrical power supply network in the pumping stations and related buildings.

All equipment shall be to class of protection IP55 as a minimum.

The works include:

a) Distribution boards
b) Secondary distribution boards if specified
c) Cabling and wiring
d) Installation of wiring in conduits for lighting, socket-outlets and outlet boxes starting from main and secondary boards, as well as the lighting points, socket outlets, and outlet boxes.
e) Internal and external lighting Luminaires.
f) Grounding systems.

406.2 ELECTRICITY SUPPLY

The electrical supply has the following features:

- Three-phase.
- 380 V between phases
- 220 V between phase and neutral
- Frequency 50 Hz

Note: voltage may vary in Lebanon +15%, -15% from the nominal value.

406.3 NATURE AND ORIGIN OF MATERIALS

406.3.1 General

All materials intended for incorporation in the works shall comply with the D.T.U. in force and the regulations for construction, and the recommendations of the International Electrotechnical Commission.

Any approval of the Engineer on the origin of materials does not release the Contractor from his responsibility in respect of the quality and the reliability of the materials supplied to site, which must always be consistent with the relevant specifications. Any change of the origin of materials previously approved shall be submitted for approval.

406.3.2 Electrical Distribution Boards

A main distribution board to be installed near the entrance to the building.

i) A cable shall supply the power to this panel from the pumping station main panel or as otherwise stated in the Particular Specification

All distribution boards shall be metallic or polyester construction, they shall be monocellular, rectangular and have a plane front face, designed for built in or surface mounting as specified. They shall have a lockable door and a key.

They shall have class of protection IP55 and be finished with textured paint RAL 7032 or RAL 7035.

Secondary distribution boards shall be installed according to the specification and the electrical installation drawings. These boards shall comprise:

Distribution boards shall be supplied with all wiring, bus-bars, equipment such as circuit breakers, ammeters, voltmeter selector switch etc..., accessories, cables, junction boxes, and installation material ready for installation directly on arrival at site.

The boards shall be designed to facilitate inspection, maintenance and repair and all articles having the same characteristics and dimensions shall be entirely interchangeable.

Distribution boards must not show any deformation or welding effect. They shall be rigid enough to support the equipment without deformation both during normal operation and under short circuit condition. They shall be fitted with reinforcement especially against the effect of short-circuits.

All bus-bars, equipment and connections shall withstand the nominal rated current continuously without heating beyond admissible values.

The design of distribution boards shall take into consideration every change of rating of the equipment to suit the climatic conditions specific to the site. All live terminals and parts shall be adequately insulated from the frame of the panel board. Metallic boards frame shall be grounded.

Bus-bars shall be so protected as to exclude the possibility of contact with them or any live part when closing or releasing circuit breakers.

Boards comprising several cells, shall be protected with an earthing bar covering the entire length of the board.

Frames and the metallic enclosures of equipment shall be connected to the earthing bar by means of approved accessories.

Each single phase distribution board shall have one bus-bar and one neutral bar. The section of the bars shall be sufficient to allow the passage of the nominal current without leading to excessive heating, the rating shall be equivalent to at least the total nominal current of incoming circuit breakers in the board.

Bus-bars shall be made of electrolytic copper. The Contractor may offer variants made of another material, but in this case, he shall submit for the Engineer's approval all the details concerning the accessories required for the connection of cables and equipment to bus-bars.

The frames of metallic distribution boards shall be treated against corrosion. They shall be painted internally and externally with one coat of primer and two grey finishing coats.

All circuits fed from the panel board shall be labelled.

Distribution boards shall have at each feeder, a chart or diagram describing, according to the distribution scheme, the circuits connected to this feeder. The boards shall be of fixed, non removable type. Circuit breakers shall be of miniature type.

Connections to all equipment shall be easily reached and made from the front without having to dismantle the board.

Ammeters shall be fitted at each incoming feeder.

406.3.3 Circuit Breakers

406.3.3.1 General Specifications

All circuit breakers shall meet the following conditions:

- They shall be designed to function under the electrical current supplied to the station.
- Each phase pole shall be fitted with an instantaneous action thermo-magnetic type over current trip. The trip shall act on a common tripping bar and provoke the simultaneous tripping of all poles.
- Circuit breakers shall be of automatic trip type.
- Each pole shall be fitted with an arc extinguishing mechanism.
- Circuit breakers shall be compensated for ambient temperature. All thermal relays shall be compensated in order to function correctly in the ambient temperature of the site.
- Circuit breakers shall be fitted

Three-phase circuit breakers shall also meet the following conditions:

- Incoming circuit breakers from the main panel board, connected directly to the transformer station shall be four pole. All other circuit breakers shall be three pole.
- All the poles of three-phase circuit breakers should trip simultaneously with one control mechanism.

Circuit breakers installed in the general panel board may be of miniature type.

Circuit breakers installed in secondary panel boards may be moulded case miniature type.

406.3.3.2 Rupturing Capacity

- All circuit breakers shall have sufficient rupturing capacity to switch off the highest short-circuit currents.

- Circuit breakers shall have the rating indicated on the drawings.

The minimum rupturing capacities shall be as tabulated hereunder and consistent with the D.T.U.

Rating (A)	Voltage (V)	Rupturing Capacity (A)
32	240-380	6000
70	240-380	6000
100	380	14000
125	380	14000
150	380	22000
500	380	30000

406.3.4 Contactors

Contactors used in the installation shall be three-pole, mounted in screened boxes, protected to class IP55. They shall be designed to function under the nominal working voltage and current corresponding to the circuit breakers protecting the circuits they control.

The mechanical and electrical resistance of the contactors shall be high and they shall be protected against dust or any other factor that might harm their proper functioning.

“On” and “Off” push-buttons shall be mounted on the cover of the box.

406.3.5 Electric cables

The cables to be installed include the following:

- Main distribution board power supply cables.
- Connection cables between the main and secondary distribution boards.
- Power supply cables to metering.
- Connection cables between meters and secondary boards.
- Cables used for the power supply of low power motors.

Multicore cables shall be protected with an external sheath made of thermoplastic material of NYA type consistent with the most recent VDE standards or of an equivalent type consistent with other recognised standards.

All cables shall be of 1000 volts rating.

Cores shall be made of pure electrolytic copper; resistivity = 0.01724 Ohm/mm^2/m at a temperature of 20ºC. They shall be multi stranded for sections exceeding 6mm^2.

The insulation of the cores shall be colour coded as specified.

406.3.6 Insulated Conductors

Conductors laid in polyethylene tube shall be made of copper insulated with thermoplastic materials. They shall be of NYA type consistent with the most recent VDE standards or of an equivalent type consistent with other recognised standards. They shall be of 600 volts rating.

Conductors shall be made of pure electrolytic copper; resistivity = 0.01724 Ohm/mm^2/m.

The minimum section of conductors shall not be less than 1.5mm^2. Conductors having sections exceeding 2.5 mm^2 shall be multi-stranded.

In single-phase circuits, the section of neutral conductors shall always be equal to that of the phase conductor. Each circuit shall have an independent neutral from the secondary panel board.

All phase-conductors of single-phase circuits shall be linked to the same phase in the distribution board.

Each phase conductor, neutral conductor and earth conductor in the installation shall be differentiated, one from the other, by the colour of the insulation.

- Each phase conductor shall have a colour different from those of the others, changing the colour for a phase conductor along the same circuit is absolutely forbidden.

- The neutral conductor shall be <u>grey</u> throughout the installation.

- Earthing conductors shall be <u>yellow-green or green</u> throughout the installation.

The Connection of conductors shall be carried out exclusively inside enclosures, by means of clamping screws in order to prevent the scattering of strands.

The use of an insulating adhesive tape is forbidden.

Maximum voltage drop in comparison with the available voltage in the main panel board: 3%

Maximum density of current: 3A/mm^2 for 2.5mm^2 cables and 2A/mm^2 for larger cables.

406.3.7 Conduits

Where electrical wires and cables, including very low voltage wiring, are installed in plastic conduit, the conduit shall be consistent with the DTU and its addenda (class of protection IP55)

The connection of conduits shall be carried out by means of accessories of the same type, using the materials specified in the catalogues of the conduit manufacturer (class of protection IP55)
Adequate flexible accessories shall be used for electric lines crossing expansion joints or fixed to different structure units.

Generally, all accessories used with electrical networks shall be of the same type and shall have the same characteristics.

Conduits shall be so installed that the junction, sub circuit, and wiring draw boxes are always accessible for maintenance and repair.

The connection of conduits or of conduits and other accessories shall be carried out according to the instructions of the conduit manufacturer.

Surface mounted conduits shall be fixed by means of galvanised steel brackets, sufficiently close to each other to ensure a solid fixing. Screws and nuts shall also be galvanised.

After laying the conduits, they shall be fixed in cement mortar.

The Contractor shall make grooves in the walls for built in conduits; in all cases he shall fix the conduits in such a way as not to damage the finish of the structure.

The use of wooden pegs for sealing is strictly forbidden.

No more than two 90º bends shall be permitted throughout the run of a conduit between two junction boxes. Should more than two bends be required, the Contractor shall install additional junction boxes in order to facilitate the laying and removal of wires.

In the event of the electrical conduits crossing other pipes, electrical conduits shall be so installed as to keep a free space between conduits and pipes.

A minimum clearance of 200mm shall be maintained between electrical conduits and heating or steam pipes. If this 200mm clearance cannot be achieved electrical conduits shall be externally insulated.

Conduits embedded in walls shall be vertical or horizontal. Installation of diagonal conduits inside walls is not permitted.

Surface mounted conduits shall run parallel or perpendicular to walls.

Note: All low voltage cables shall be installed in separate conduits.

The internal diameters of various sizes of conduit are tabulated hereunder together with the number and section of conductors that may be installed therein. The numbers stated in the table represent in millimetres the minimum internal diameters. The Contractor shall supply conduits having a diameter equal to at least that specified.

Section of Conductors (mm^2)	Number of Conductors in Conduit			
	3	4	5	6
2.5	16	16	16	16
4	16	16	16	16
6	16	16	16	23
10	21	21	21	29
16	21	29	36	36
25	36	36	36	48
35	36	48	48	48

No more than 6 conductors may be installed in one conduit unless the seventh is an earthing conductor.

406.3.8 Boxes

Boxes used for connections and sub circuits, as well as those installed at each feeder, shall be supplied with appropriate covers (class of protection IP55)

They shall have knockouts for conduit connections.

Switch and socket boxes shall be provided for the switches and sockets to be installed, in conformity with the recommendations of the supplier of these items.

Surface mounted boxes shall be watertight to IP55, of moulded construction with inlets fitted with glands.

Junction boxes installed outdoors or inside humid locations shall be watertight weatherproof type (class of protection IP55)

Power supply circuits of low power equipment such as fans and air convectors shall be linked to junction boxes with fixed connections for the corresponding equipment.

Junction boxes shall be either single-phase or three-phase.

406.3.9 Switches

Lighting circuit switches shall be single two, or three way rated for 16 Amp, 250V. They shall be silent toggle switches.

The switch and cover plate shall be fixed to the box with stainless steel or chromium-plated screws. Hook fixings are forbidden.

Flush switches shall have their covers made of an insulating material (class of protection IP55)

Switches shall be flush or surface mounted according to the type of installation.

Surface mounted switches shall have the same mechanism as flush switches, but shall be installed inside dust proof boxes, having inlets fitted with glands (class of protection IP55)

Switches shall be installed on phase wires and in no case on neutral wires.

Switches shall, in general, be installed 1100mm above the finished level of the floor, except in particular cases where their installation shall be submitted for the Engineer’s approval.

Switches intended for the same duty in different locations shall be installed at the same heights. Switches shall always be installed in the most suitable places for their operation.

406.3.10 Power Outlets Sockets

406.3.10.1 General

The exact locations of power-outlet sockets shall be determined according to the construction details of the building. These locations shall be submitted for the Engineer’s approval.

Power outlet sockets shall be flush or surface mounted according to the type of the installation.

Flush mounted socket outlets shall be installed in their boxes with screws.

All single-phase power-outlet sockets and plugs shall have ground contacts or terminals to be connected to the grounding system.

Three-phase power-outlet sockets shall be installed at heights which suit the equipment they supply with power.

Power-outlet sockets intended for the same duty in different locations shall be installed at the same heights.

Three-phase power outlet sockets shall be supplied with corresponding plugs.

406.3.10.2 Single Phase Power-Outlets (1-Ph P.O.)

Each single-phase power-outlet socketsand plug shall have 2 terminals and one ground contact. They shall be rated for 10/16 Amp and 20Amp-250V.

Fixing the switch and cover plate to the box shall be done with stainless steel or chromium plated screws. Hook fixings are forbidden.

Switches used with built-in installations shall be of flush type and fitted with square or rectangular covers made of an insulating material.

Surface mounted switches shall be installed inside waterproof boxes (class of protection IP55). These boxes shall have inlets fitted with glands and shall be provided with knockouts.

It shall not be possible to insert telephone plus into power outlet sockets.

406.3.10.3 Three-phase Power-Outlet Sockets (3-Ph P.O.)

Three-phase socket-power and socketsplugs shall be rated for 32 Amp, 380V and shall have ground terminals.

Surface mounted power-outlet sockets shall be installed inside water-proof boxes (class of protection IP55) or better. These boxes shall have inlets fitted with glands and shall be provided with knockouts.

It shall not be possible to insert telephone plugs into sockets.

406.3.11 Grounding Systems

406.3.11.1 General

The following independent grounding systems may be utilised.

Grounding system of the neutral point of the Standby generating set alternator.

Grounding system of the metallic frame of the main panel board.

Grounding system of the building or metering system.

These systems shall have a resistance of less than 5 Ohms.

406.3.11.2 Installation

Each grounding system, shall be achieved by one or several rods.

The resistance of the grounding shall not exceed the value stated in the previous paragraph.

The Contractor shall install a sufficient number of rods to achieve this resistance value.

Grounding rods shall consist of a steel core covered with a copper coat.

The heads of the grounding rods shall be buried 500mm deep in the ground. A concrete manhole having a 500mm side shall be prepared for each earth terminal in order to facilitate maintenance operations and later reinforcement works utilising additional elements if required to increase the earthing installation.

The manhole shall have a cast iron or concrete cover allowing permanent access.

The head of each grounding terminal shall be fitted with a sectioning bar allowing the isolation of this grounding element from the installation and, hence, the measurement of the ground resistance.

The connection of grounding cables to the earthing system shall be carried out by means of sockets ensuring very good contact.

406.3.11.3 Grounding Conductors

The sections of grounding conductors of the various terminal circuits or power supply circuits of a panel shall be the same as those of the neutral conductor of the corresponding circuit, in such a way that they are not less than $2.5mm^2$ nor more than $70mm^2$.

Connections shall be carried out by permanent weld or by screw clamping.

Connections between the grounding network and equipment subject to movement shall be carried out by means of copper braids having the same sections as grounding conductors.

Series grounding is prohibited.

All insulated grounding conductors shall be yellow-green (external colour). This colour shall not be used for any other part of the installation.

406.3.12 Lighting Fixtures

406.3.12.1 General Conditions

The installation of the lighting system shall be consistent with the technical specifications generally, and particular attention shall be given to those related to humid and corrosive situations (chlorine).

Lighting installations shall be complete and shall include all necessary accessories, whether the accessories are described hereunder with the description of the lighting installation or not.

The body of the lighting fixture, its base, or support shall entirely cover the corresponding box.

External devices shall be mounted with non-ferrous accessories.

The frame of lighting devices inserted in a false-ceiling shall not allow light to infiltrate between the frame and the false-ceiling.

Lighting devices fixed directly to a centre box shall be solidly held by a peg and a cramping block.

406.3.13 Characteristics of Materials

406.3.13.1 General

- Unless otherwise stated on the drawings lighting devices shall, wherever applicable, comply with all conditions stated below.

- The name of a supplier and catalogue number are stated for reference only as a description of type and standard. The equipment supplied shall be consistent with the specifications and, if necessary, standard equipment shall be modified accordingly.

406.3.13.2 Wiring

Wiring inside lighting devices shall have a section equal to or exceeding $2mm^2$, and shall be insulated for a nominal voltage of 500V.

406.3.13.3 Sheets

The minimum thickness of sheet used in lighting devices shall be 1mm.

Metallic parts of lighting devices shall be free from any scratch.

406.3.13.4 Treatment and Painting of Sheets

- All sheets shall receive the following treatment:
  Prewashing, grease removal, rinsing, passivating, drying.
- Unless otherwise specified, all non reflecting surfaces, such as the frames of lighting devices, bases, etc.. shall be coated with an enamel finish. The colour of the paint shall comply with the specifications unless specified otherwise by the Engineer.
- All reflecting surfaces shall be coated with a white enamel having a minimum reflection coefficient of 80%.

406.3.14 Fluorescent Luminaires

406.3.14.1 General

Flush Luminaires shall be so dimensioned as to allow the replacement of one or more sections of the false-ceiling without requiring any cutting.

406.3.14.2 Bushes

Lighting devices shall be equipped with white clip-on bushes.

406.3.14.3 Ballasts

Ballasts shall be consistent with the standards of the D.T.U. and designed for 45^oC ambient temperature. Only one or two-lamp ballasts shall be used.

Ballasts shall be completely enclosed inside a metallic casing and shall have a corrosion-resistant finish.

Windings shall be impregnated with a polyester resin suppressing every risk of softening and melting and ensuring excellent heat dissipation.

Ballasts shall be corrected to give a power factor better than 0.9.

Ballasts shall be of silent-type operation and unless otherwise provided for, shall be rapid start type.

Two series-lamp ballasts shall be lead-lag type or equivalent.

406.3.15 Incandescent Luminaires

a) Incandescent Luminaires shall be fitted with porcelain-base bushes having an Edison screw E27 for lamps up to 200W, and Goliath screw E40 for lamps of 300W or more.

b) It shall be possible to place and remove lamps without dismantling the system.

c) The various types of incandescent Luminaires shall comply with the detailed description given by the manufacturer.

406.3.16 Lamps

406.3.16.1 General

Lamps shall be supplied and placed in all the lighting fixtures as specified.

Prior to the final commissioning of electrical installations, lamps used throughout the works shall be replaced by new ones.

406.3.16.2 Incandescent Lamps

Incandescent lamps shall be of the internal satin type with screw bases.

Lamps shall be designed to work at 220V (or 24V) voltage, they shall have a lifetime of a minimum 1000 hours.

406.3.16.3 Fluorescent Lamps

Unless otherwise specified, fluorescent lamps shall be rapid start type. They shall have a high luminous efficiency.

406.3.16.4 Halogen lamps

Halogen lamps shall be tubular type, having a lifetime of at least 4000 hours and operating in all directions and positions.

The colour temperature shall be 2850ºC, the fuse shall be incorporated and the flux value is 5000 lumen.

Particular Cases: Lighting of Humid Buildings

Given the humid atmosphere inside pumping, treatment and other similar areas, 200 Volts should not be used for the lighting system without a security mechanism.

The Contractor shall install a special security mechanism in the following manner:

The outgoing supply cable shall be equipped with an isolating transformer and a power circuit breaker fitted with differential protecting devices of adjustable sensitivity and delays: 03A, 1A, 3A up to one second.

The rupturing capacity shall be 20KA in accordance with D.T.U.

NB All equipment used in the buildings shall be standard (Class of protection IP55 minimum) and shall comply with international technical regulations.

406.3.17 Emergency lighting

Emergency lighting shall be provided to maintain sufficient illumination in accordance with BS 5266 for escape routes within the building during mains supply failures.

Luminaires shall comprise at least a single 8w fluorescent tube with a solid state changeover circuit and high efficiency, high frequency inverter all contained within a die-cast aluminium bulkhead body, having a corrosion resistant, stove enamel finish. The diffuser shall be of unbreakable opal polycarbonate material, secured by an oil and water proof sealing gasket to result in a luminaire rated to IP65.

Luminaires shall be self-contained and shall incorporate a maintenance free, nickel cadmium battery, capable of preserving the light output for a period of at least 3 hours without mains supply, together with an automatic recharging circuit to restore the charge within 24 hours of total discharge. Each luminaire shall incorporate an indicator to show that the charger circuit is healthy and have a removable gear tray and fused terminal blocks for ease of maintenance and installation.

Unless otherwise specified, luminaires shall be either of the following forms:

a) maintained form, normally lit from the mains and automatically switched from mains to battery during mains failure;

b) non-maintained form, energised automatically from the battery supply only when the mains fails and the associated local lighting circuit is switched on;

c) sustained form, having two lamps, one of which is mains fed only, the other operating from the battery supply during mains failure

406.4 EXECUTION OF THE WORKS

406.4.1 Locations for Installation of Equipment

The general locations for the installation of materials shall be as shown on the drawings. These locations shall be agreed on site between the Contractor and the Engineer or his representative.

406.4.1.1 Distribution Panel Boards

Unless otherwise directed, Panel boards shall be centered 1.50m above finished floor level.

Distribution boards shall be totally protected and fitted with circuit breakers. In three-phase panel boards, the numbering of circuits indicated on the drawings is based on a three-phase separation where circuits are connected respectively to the red, yellow and blue phase.

Internal equipment of panel boards (bus bars, circuit breakers,...) shall only be installed in the enclosure after installation, fixing and connecting conduits.

All openings left in the panel shall be properly sealed.

Distribution panels shall be installed vertically; under no circumstances shall the conduits serve as supports to the panel.

The sides of panels to be embedded shall be covered before installation with a thick coat of emulsified tar.

The frames of built-in panel boards shall be installed squarely and in alignment with the walls.

Each distribution panel shall have at the front side an engraved plate stating the name and reference letters of the panel board. On the inside of each panel board door, there shall be a list stating the reference number for each circuit connected to the panel board and the reference number of the locations supplied with power by the circuit.

406.5 CABLE INSTALLATION

406.5.1 General Conditions

Cable installations shall conform to the following.

a) The methods used for the installation of cables shall not damage the conductors and the insulators.
b) The pull utilised for installation of cable shall be kept to the minimum necessary for installation and shall not permanently strain the conductors.
c) The connection of wires to equipment shall not be subject to any strain.
d) The radius of curvature of cables shall, at no point, be less than 10 times the outside diameter.
e) Between any two sub circuit boxes, cables shall be continuous, no junctions shall be allowed.
f) The use of wooden pins for sealing is forbidden.
g) Cables shall be marked every 10 metres in order to facilitate identification.

406.5.2 Installation of visible Cables

All visible cables shall be mounted as follows:

a) Cables shall be installed on cable tray in one layer and shall in no case be superimposed. Each cable tray, shall have a 25% reserve in order to allow for the installation of future cables. Vertical sections shall be fitted with cable fixing devices.

b) Cables shall be fixed on masonry along walls by means of galvanised steel brackets or other means proposed by the Contractor and approved by the Engineer.
c) Beneath ceilings, cables shall be held by substantial supports. The supports shall be sufficiently close to avoid droop of the cables.

406.5.3 Other Conditions

Lengths of cables mounted between ground and a height of 2.50m and those crossing masonry shall be installed inside galvanised steel tube.

406.5.4 Insulated Wires

All wires and connection devices shall be accessible for inspection and replacement as required. They shall be so set out and installed as to allow handling without causing any mechanical deterioration.

All wires shall be installed entirely inside conduits.

The pulling of wires in conduits shall be carried out carefully in order not to damage the insulator. It is forbidden to use oils, grease or any other fluid for facilitating the pulling of wires, the contractor can however use powder of an approved type.

407. TELEPHONE INSTALLATION

407.1 GENERAL

The required installation shall comprise:

a) Main distribution boxes
b) Secondary distribution boxes for each office unit.
c) Distribution circuits
d) Telephone plugs

407.2 CIRCUITS DISTRIBUTION

a) Cables required for this installation shall have copper conductors of 0.5mm in diameter, except for the earthing conductor which shall have a sufficient diameter according to the number of socket-outlets and plugs it connects. All cables shall be insulated with PVC sheathing.

   Cables shall be divided into three categories:

   - Multicore cables between main distribution and main distribution boxes of various floors and locations. The capacity of these cables shall be equal to the number of conductors required for each distribution box, in the 25% spare capacity.

   - Two-core cables between secondary distribution boxes or main distribution boxes and telephone plugs. An appropriate main circuit shall be installed for each telephone plug.

b) All cables shall be laid in conduits identical to those used in electrical installations. The section of the conduit shall be, as a minimum, two times larger than the total section of cables (including insulation) it is designed to house.

407.3 TELEPHONE PLUGS

Telephone plugs shall be built in or surface mounted. They shall have the same brand name as socket-outlets and plugs.

PART 5

INSTRUMENTATION AND CONTROL

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501. GENERAL REQUIREMENTS FOR INSTRUMENTATION & CONTROL

501.1 ABBREVIATIONS

The following abbreviations are used in these documents :

1/head/day	liters per head per day
AC	Asbestos Cement
AGMA	American Gear Manufacturer’s Association
AOD	Above ordnance datum
BS	British Standard
CDR	Council for Development and Reconstruction.
CFM	cubic feet per minute
Ch	Chainage
CMR	Continuos Maximum Rating
CP	Code of Practice
CPU	Central Processing Unit
DI	Ductile Iron
DIN	Deutsch Industrie Normen
DOV	Double Orifice Valve
DPSK	Differential Phase Shift Keying
DTU	Documents Techniques Unifiés
EDL	Electricity of Lebanon
EMC	Electromagnetic Compatibility
EOH	End of hole.
FDS	Functional Design Specification
FIDIC	Federation Internationale des Ingénieurs- Conseils
FSK	Frequency Shift Keying
g	acceleration due to gravity ($9.807 m/s^2$)
GL	Ground level
gpm	gallons per minute
gr	gram
GRP	Glass Reinforced Plastic
GTSD	General Technical Specification Document
hr	hour
I/O	Input / Output
IEE	Institute of Electrical Engineer
ISO	International Standards Organization
ITS	Institute of Technical Studies
kgf	kilogram force
kPa	kilo Pascal
kVA	kilovolt-ampere
kW	kilowatts
kWh	kilowatt hour
LED	Light Emitting Diode
m	meters
m/s^2	meters per second per second
m^3	cubic meters
m^3/day	cubic meters per day
MDPE	Medium Density Polyethylene

mgd	million gallons per day
mhd	meters head
mm	millimeters
NFE	Normes Françaises - (Electrical)
NLQ	Near Letter Quality
NPSH	Net Positive Suction Head
PS	Particular Specification
PTT	Poste de Téléphone et de Télégraphe
PVC	Polyvinyl Chloride
PWL	Pumping Water Level
RAM	Random Access Memory
RBC	Rotating Biological Contactor
RTR	Reinforced Thermoplastic Resin
RTU	Remote Terminal Unit
SCADA	Supervisory Control And Data Acquisition
SPDT	Signal Pole Double Throw
SSU	System Supervisory Unit
SWL	Static Water Level
TDM	Time Division Multiplex
TDH	Total Dynamic Head
TEFC	Totally Enclosed Fan Cooled
UHF	Ultra High Frequency
UPS	Uninterrupted Power Supply
UPVE	Unsaturated Polyvinyl Chloride
VDU	Video Display Unit
VGA	Video Graphics Array
VHF	Very High Frequency
VHS	Video Home System

501.2 DESIGN AND ELECTROMAGNETIC COMPATIBILITY

All circuits and equipment shall be designed in accordance with good engineering practice and particular care shall be taken to ensure that no component shall exceed its maximum voltage/current/power ratings at any time, including during transient surges.

All instrumentation equipment shall be protected from interference emanating from radio frequency transmissions, either radiated or cable borne, such that it shall not cause malfunction of the system or damage to the components.

All equipment supplied shall not radiate any form of electromagnetic energy in amounts that might interfere with external equipment or instrumentation.

The latest standards on interference and the principles of electromagnetic compatibility (EMC) IEC 801-2 to IEC 801-5 shall be followed. The electrostatic discharge (ESD) and surge immunity shall be applied to the design of the plant and applications.

501.3 INTERRELATION WITH OTHER SECTIONS

Requirements given in other sections shall be applicable wherever relevant to equipment or materials specified in this Section.

Thus indicator gauges, meters, enclosures, panel construction, finish, components, wiring, terminations, cabling requirements and environmental operating conditions shall be in accordance with the relevant clauses of the Mechanical and Electrical Sections unless specifically amended in this Section.

501.4 INTERRELATION WITH OTHER CONTRACTS

Where the location, installation or connection of any components of instrumentation are arranged by the Engineer under other contracts, it shall be the responsibility of the Instrumentation Contractor to advise and provide all relevant information on such matters to the Engineer in order that the correct and proper performance of the Contractors instrumentation is not prevented or impaired.

501.5 TEMPERATURE AND HUMIDITY

All supplied equipment shall function without error and shall be constructed of such materials or so treated as to prevent the formation of mould, fungus or any corrosion over the ranges of temperature and relative humidity specified in the specific clauses for this site.

501.6 ENCLOSURE PROTECTION

Instrumentation and hardware mounted in the field shall be contained in suitable enclosures to provide ingress protection to BS EN 60529 rating indoors dry and wet locations IP55 and IP65 outdoors as a minimum. Sensors installed below water level or liable to submersion shall be rated to IP 68. Where items are fitted in a panel or other enclosure, they shall preserve the design IP rating of that enclosure.

501.7 VOLTAGE AND FREQUENCY TOLERANCE

Equipment shall be capable of working from a supply whose voltage may vary ± 15%, and tolerate any transients that could be experienced in such an environment without programme corruption or system failure.

501.8 INSTRUMENTS

Each instrument and sensor shall be selected considering all the relevant performance parameters for the principle of measurement adopted, its intended use and the particular process in question.

All instrument output signals shall be volt-free, clean contacts rated at 220v AC 2A for digital and 4-20mA continuous proportional linear signal for analogue. Pulsed outputs suitable for integration counter drives shall be 24V DC.

501.9 INPUTS, OUTPUTS AND SIGNAL LOOPS

Opto-isolation shall be provided on all input and output interfaces to cards.

Digital signals shall be 24V DC with the power supply from either the associated power pack or the external instrument. Relays shall be used where more than one instrument including I/O are fed from a single signal.

Analogue signals shall be continuous linear scaled signals with a 4-20 mA operating range. Loops with instruments wired in series (e.g. panel mounted indicator and RTU input) shall have zener diodes fitted across each subsequent instrument leg to ensure loop integrity.

501.10 TERMINALS

Signal terminals shall be the disconnect type. Power supply terminals shall be shrouded and clearly marked with the appropriate warning tags. LED's shall be provided for fault tracing, if not supplied on the I/O cards. LED's in either case must be clearly visible from the front, with only the enclosure door open.

For each incoming screened cable, a separate earth terminal shall be provided for screen termination to earth.

All equipment, isolators, terminals and cables shall be clearly marked. 20% spare terminals shall be provided.

501.11 PROGRAMMING AND MONITORING UNIT

If computers, PLC’s and specialised systems, such as Control & Monitoring systems, SCADA, Data logging or systems with embedded microchips, are date-sensitive, these systems operation shall not be affected upon the change of Century.

Hand-held portable devices shall be provided for each item allowing user configurable operation and to enable the downloading or uploading of data or software and the local running of diagnostic software. For RTU plc's the device shall be fully compatible with the RTU and shall be supplied with:

a) Software to enable the development of programmes and the subsequent downloading to the RTU.

b) Software to enable full communications with the RTU and to:

   i. upload data or alter data in the RTU;
   ii. access communications ports and I/O.

c) Full page process mimic display capability.

501.12 DISCRETE COMPONENTS

All discrete resistors, capacitors, switches, relays, diodes, transistors and other electronic devices shall comply with the BS 9000 series specification for components of assessed quality.

The Engineer's agreement must be sought before using components that are not certified, but it will remain the Contractor's responsibility to ensure that all components are suitable for the application.

Similar types of components shall be of the same manufacture and design wherever possible.

501.13 INTEGRATED CIRCUITS

All integrated circuits shall be of a proven design and shall be clearly marked with the original manufacturer's identity and device number.

501.14 SUB-MINIATURE SWITCHES

Where DIP or other sub-miniature switches are used they shall be provided with a cover, or other means of protection, to prevent accidental switching during handling.

501.15 PRINTED CIRCUIT BOARDS

Printed circuit boards shall be made of glass fibre with copper trackwork, all exposed copper being tinned prior to assembly, and the board and components cleared of flux before a thin layer of clear varnish is applied for environmental protection.

The board and its components shall be identified by references relating to the corresponding circuit diagram which shall be printed on the component side of each board. Where a number of boards are mounted in a rack system, the rack and boards shall be clearly marked to identify each board to its particular position.

501.16 SOCKETS AND CONNECTORS

The use of plug-in connectors for electronic equipment shall be kept to a minimum, and all circuit components including integrated circuit chips shall have soldered connections where this is permitted by the chip manufacturer.

Where sockets and connectors are incorporated in the design, they shall have self-cleaning, hard gold alloy plated, wiping action contact faces, and incorporate polarising keys or similar means to prevent incorrect mating. Insulation displacement type connectors shall not be used.

All light current wiring having a cross-section of $1.0mm^2$ or less shall have tinned copper conductors.

501.17 TEST FACILITIES

The electronic equipment is to include built-in test facilities to permit the detection and replacement of faulty modules without the use of oscilloscopes, signal generators, or other sophisticated test equipment.

501.18 SURGE PROTECTION

All telecommunication lines, data and signal cables and other items of equipment external to the building environment prone to damage resulting from induced surges due to lightning discharges, shall be fitted with lightning surge protection barrier devices at each end of the line to suppress and divert any transients likely to cause damage to the connected equipment.

All surge diverters/lightning arresters fitted to telecommunication lines shall be of a design approved by the telecommunications authority.

Surge protection units shall be un-fused, solid state devices, designed to limit the transient over-voltages to not more than twice the normal working voltage of the line. They shall have low in-line resistance and automatically return to normal operation after diverting a surge.

The units shall have provision for either DIN rail or individual panel mounting or direct bolted connection to a suitable copper earth bar.

The location of the units shall be arranged such that the earth connection shall be routed clear of the protected signal cables and have short, straight connections without sharp bends to the main earth points, using copper conductors not less than $16mm^2$ csa and not greater than 5 metres in length to provide a low impedance path.

Surge suppression devices to provide protection from mains switching or other supply network disturbances shall be incorporated or fitted to all sensitive monitoring or control devices. They shall be designed to filter un-wanted transients and limit the 'let-through' voltage to less than twice the working mains voltage, between all conductors and each conductor and earth. Protection monitoring status indication shall be fitted.

502. INSTRUMENTATION

502.1 INDICATING INSTRUMENTS

502.1.1 General Requirements

Indicating instruments shall conform to the following standards:

BS 5458	IEC 51	VDE 0410
BS 7194	IEC 414	VDE 0411
BS 5164		
BS 89		

Indicating instruments shall show the specified measured values in either electro-mechanical or electronic and analogue or digital form, as defined in the Particular Specifications.

Instrument cases shall be made of magnetic sheet metal providing further protection against external magnetic fields. The instruments shall be termite and fungus resistant and shall be self extinguishing.

All indicating instruments shall withstand a minimum of 20% current and/or voltage overload.

All instruments and their accessories shall be suitable to operate between -25ºC and 50ºC at 85% maximum humidity for 60 days without condensation.

All instruments shall be shock proof and they shall not be affected by vibration. They shall have an insulation of 2 KV at 50 Hz.

Wherever possible, panel mounting indicating instruments shall be of matching size, appearance and orientation and suitably scaled, all in accordance with the general requirements for electrical panels.

All indicating instruments shall be of a similar flush vertical mounting, rectangular pattern, enclosed in black coloured, dust and damp-proof cases, one side being not less than 90mm (3.5") long or as specified. Scaling shall be in approved metric units normally ranged from zero to 20% - 40% above the system designed operating value, except where finite limits exist (e.g. p.f. indicators, synchroscopes) or where restricted ranges are specified. Adjustable set points within the instrument ranges shall be incorporated as specified.

Instruments having a mechanical movement shall provide at least a 90° scaled arc. 240° arc scales shall be employed on principal specified indicators.

Ammeters for motor circuits shall have an extended scale to cater for the starting current. These shall have adjustable red pointers or red markings on the scale to indicate the normal circuit current for the associated plant and shall be connected to each of the three phases of a three phase motor circuit.

502.1.2 Analogue Instruments

Analogue indicating instrument shall be of the moving iron or moving coil and fixed magnet type.

They shall have a class 1.5 accuracy.

502.1.3 Digital Instruments

Digital indicating instruments shall have the following characteristics:

- A seven (7) segment, LED display
- Polarity indication
- Protection against incorrect polarity
- Minimum digit height of 14 mm.
- 1 to 5 reading update per second
- Automatic zero adjustment
- Class 1 + 1 digit accuracy
- Minimum insulation resistance of 10 M Ω

502.1.4 Strip Indicators

Strip indicators shall be provided for the specified functions and arranged as shown on the proposed panel layout.

The indicators shall be solid state electronic type employing a column of neon gas plasma bars, illuminated consecutively in proportion to the input signal. The scale length shall be at least 100mm and allow on-line span and zero adjustment.

All indications shall be driven from transducers or inputs giving analogue signals of 4-20 mA.

502.1.5 Indication Lights

Signalling and alarm lamps, shall have standard drilling diameters ∅ 22 or modular sizes.

Indication lights shall be flush panel-mounted types with bodies fastened and keyed so that the lamps shall be capable of replacement from the front of the apparatus without disturbance to the lamp holder or panel wiring. Lens colours shall be as specified below. Bezels shall be coloured black.

signalling lamp (white) : main power supply ON
signalling lamp (red) : fault
signalling lamp (white) : RUN
signalling lamp (green) : standby ready to start
signalling lamp (blue) : level of tank
fixed or flickering signalling lamp (yellow or orange) : minor defect

All light sources shall be operated at Extra Low Voltage. Single units shall be fitted with MES caps and be illuminated by LED clusters where colours permit, otherwise filament lamps shall be used.
To extend lamp life, filament lamps shall be arranged to operate at approximately 20% below their rated voltage and details of voltage and type of indication lamp shall be submitted for the Engineers approval. Particular consideration shall be given to circuits operated from a battery supply permanently floating across a charging circuit, where the terminal voltage may be higher than the nominal voltage.

When annunciator style indicators are used they shall incorporate two lamps wired in parallel for each fascia which shall have a window area of not less than 48mm x 24mm. The engraved characters shall be not less than 3mm in height and shall be filled black on a translucent background coloured as specified.

Alternatively where specified (particularly for unattended situations) self-contained LED annunciator display modules shall be used and configured for panel mounting. Legend plates shall be provided adjacent to each indicator. Where message display indicators are used, they shall have programmable legends and adjustable pulse rates.

502.1.6 Indicator/Recorders

Electro-mechanical indicator/recorder shall be a flush, panel mounting, single/multi pen indicator/recorder, scaled and labelled as specified herein. The initiating signals for each pen and the trace colour(s), together with any event markers and/or alarm settings, shall be as specified.

Continuously running recorders shall run at a speed of 20mm/hour with date and time annotation at 4 hourly intervals. For intermittent running, as in storm pumping applications, the recorder chart speed shall be 60mm/hour and shall only be initiated when the level approaches the first pump start level and be stopped 30 minutes after the final pump cuts out. Starting and stopping times and dates shall be printed on the chart and each pump operation shall be individually annotated by means of a single trace for each pump showing its running time.

To provide minimum time lags between other channels on the recorder, dot printouts may be used where required.

The Z folded chart paper shall be 250/100mm wide, linearly scaled in half hourly divisions and the width shall be calibrated 0-50 divisions linearly or logarithmically scaled as specified, to adequately show the normal range of operation and include the maximum possible signal. The chart shall run for a minimum period of 30 days and 24 spare charts shall be provided. Circular charts shall be 105mm wide, 7 day graduated.-

Each channel shall provide a continuous ribbon strip visible indication over a calibrated scale (left hand zero) and an individually different coloured trace on the chart by means of either fibre tipped pens fed from disposable ink cartridges or electrical writing or sensitised paper.

Each input shall be separate and isolated from the conditioning amplifiers and all necessary computing modules shall be included in the unit to provide the required indications.

The following features shall be provided for the operator control, accessible from the front without withdrawing the unit during operation:

(a) Pen renewal (if relevant).

(b) Power on/off switch.

(c) Chart drive on/off switch.

(d) Chart replacement and adjustment.

Adjustable high and low, volt free alarm contacts shall be provided on each channel and incorporated into the control scheme as required to initiate the alarms as specified.

502.1.7 Time Indicator

A mains driven synchronous type clock shall be suitable for front of panel mounting and resetting.

The display shall be either digital or analogue as specified and based on a 24 hr notation. The digital display shall be of white figures (not less than 55mm high), on a black background. The analogue display shall be dual scaled showing 0-12 hr black figures and 13-24 hr red figures on a white faced dial of not less than 220mm diameter.

The mains supply for the clock shall be via a suitably fused clock connector mounted in the panel, connected such that the clock is energised from the live side of the panel isolator.

502.1.8 Indicator Gauges

All gauges shall be constructed with non-corrodible metal cases and stainless steel bezels. They shall be located to enable easy reading by the plant operator and mounted to preclude damage due to vibration. The cases shall be at least 50mm dia. unless otherwise specified, scaled in metric units and normally ranged over a 240° arc from zero to 20% - 40% above the system designed operating value for full load conditions; except where finite limits exist, eg. level/contents gauges which shall be ranged 0-100%, or where restricted ranges are specified.

A schedule of gauges shall be provided for approval, detailing arrangements, scale ranges, designation label inscriptions and any alarm contacts.

Labels shall be securely attached on or adjacent to each gauge and groups of any such instruments shall be of matching appearance and approved layout.

Pressure gauges shall be of the Bourdon tube or diaphragm type. Each gauge shall incorporate a surge damping device and be fitted with its own stainless steel isolating cock.

Pressure gauges incorporating transducers for remote monitoring shall be damped to provide a steady output. The pressure at the tapping point shall give a direct indication on the gauge as well as driving the transducer. Any alarm contact settings shall be independent of the transducer function and neither shall interfere with the direct gauge indication.

Temperature gauges shall be of a type suitable for the application with the sensing element mounted within a thermal well. Where specified, the maximum working temperature under full load conditions shall be marked by means of a preset red pointer.

Pumping station water pressure gauges shall have a dial diameter of not less than 100mm and be calibrated in metres head. The gauges shall be uncorrected for datum and show actual pressure at the tapping point. The label bearing the designation given in the gauge schedule shall include the Ordnance Datum level of the tapping point.

Pump delivery and station delivery pressure gauges shall be mounted at a convenient height for reading. Suction and delivery gauges and their isolating cocks may be mounted direct on the tapping bosses and shall be adequately supported.

502.2 CURRENT AND VOLTAGE TRANSDUCERS

Current and voltage transducers shall have the following characteristics:

– Class 0.5 accuracy
– 100 ms minimum response time
– Three (3) times nominal current (In) continuous overload for current transducers
– 20% overload for voltage transducers
– Incorrect polarity protection

502.3 CAPACITIVE DEVICES

Level monitoring shall be by means of a capacitance electrode suitable for the medium and environmental conditions specified such that the electrode capacitance varies in proportion to the immersed electrode length and be arranged to provide a 4 - 20 mA output proportional to the specified level range on a scaled indicator giving a continuous read out.

Auxiliary switches shall be provided for high level alarm, low level alarm and control of external equipment. The position of all switches being adjustable over the level range.

Any fault in the electrode connection and in the electronic circuits shall provide an electrically isolated alarm signal for remote monitoring.

The electrode housing shall be a heavy duty pattern to IP 68 suitable for 2" flange mounting and incorporate a 20mm ET cable entry. The head shall be removable for cabling and servicing without disturbing the electrode mounting.

502.4 PRESSURE TRANSDUCERS

Pressure monitoring shall be by a transducer suitable for the medium and pressure/level range specified herein.

Each transducer shall be ranged to provide adequate sensitivity over the working range and be capable of sustaining a 400% overpressure without damage. They shall be of rugged and waterproof design, employing a pressure sensitive element within a stainless steel enclosure having an isolation diaphragm, suitable for either free wire suspension in the medium or fitted with a BSP thread for external connection to the relevant pipe tapping.

Suspended sensors shall be mounted in accordance with the manufacturer's instructions within a UPVC or HDPPE 'stilling tube' of sufficient nominal bore to enable easy withdrawal of the sensor.

Sensors shall be enclosed to IP 68, offer a long life and shall be supplied complete with a suitable signal cable to reach the approved point of termination transmitter-converter without intermediate joints.

The position of the equipment shall be such that withdrawal and installation can be achieved easily.

Cable entry shall be by integral sealed assembly or by 20mm conduit entry into a sealed watertight terminal enclosure with provision for transducer venting.

A transmitter shall be provided either integral with the transducer or separately mounted as specified, suitable for operation from the mains or battery supply or UPS specified (not greater than 24V) and converting the signals received from the transducer to a 4 - 20 mA signal proportional to the range specified which shall be used as follows:

(i) To drive an indicator/recorder to give a continuous readout;

(ii) To operate separate on/off pre-set adjustable points.

The transmitter shall have provision for range and zero adjustment.

For use in hazardous areas as specified, the units shall be certified intrinsically safe Ex (I).

502.5 ULTRASONIC DEVICES

Flow or level monitoring by non-contact ultrasonic measuring devices shall incorporate ambient temperature compensation and adjustable datum setting facilities. Where specified, the output shall be computed to give a flow reading for the given parameters and/or control of pumps.

i. **Transducer**The sensor head shall be protected to IP 68, mounted to provide an unhindered beam path, prevent unwanted reflections, within easy reach of maintenance personnel and, where possible, be clear of flood conditions. For sewer or foul pumping sumps, the units shall be certified intrinsically safe Ex(i) for use in hazardous areas.

ii. **Signal Converter** The converter shall be suitable for operation from the specified power supply and convert the signals received from the sensor head to a 4-20 mA signal proportional to the range specified, to be used as detailed in the Particular Specifications.

The converter shall comprise a base unit and a programming device, all in a polycarbonate enclosure to IP 65. Communication between the programmer and the signal converter shall be in such a manner that the IP rate is not prejudiced.

A minimum of 3½ digit liquid crystal display shall be used to indicate key programming features, settings and output conditions, including flow calculations to BS 3680 for flumes and weirs.

Accuracy of the signal converter shall be better than $\pm$ 1% of reading and shall have the following programmable outputs:

(a) mA proportional to user definable engineering units;
(b) SPDT relay contact output closing upon failure of the signal converter, lost echo or multiple echoes.

(c) off SPDT contact outputs with independently set trip points. These outputs shall be programmed to energise upon high/low level, rate of change or to allow a number of pump sequencing operations. Contacts rated at 5A 240V ac, non-inductive.
(d) Serial port RS 232 for down-loading data.

502.6 LEVEL CONTROL

The water level shall be monitored by a system providing the necessary duty set points, each being adjustable over the full range of control required.

To achieve performance stability under all environmental conditions and variations, all necessary signal compensation devices shall be included.

The monitoring system shall be dampened to prevent spurious switching due to transient wave motion but shall respond sufficiently to allow adequate time for plant reaction to stabilize in order to prevent hunting.

The system shall include a duplicate back-up monitoring device or have built-in self monitoring circuitry with alarm facilities.

Any high level settings which may be provided as part of a level control system may be linked with the independent high level alarm sensors specified.

502.7 FLOW SWITCH

This flow control device shall have the following characteristics:

- Body in Stainless Steel 316L
- IP65 class of protection according to DIN
- 1/2” and NPT pipe fitting
- 85°C maximum ambient temperature
- 120°C maximum fluid temperature
- Stainless Steel paddle sensing element
- 8A, 250Vac microswitch with switching contacts
- Galvanized steel base plate with ABS cover
- Mounting in all directions

The device shall be supplied with “T” connection to fit the required pipe size.

502.8 DIFFERENTIAL PRESSURE SWITCHES

Differential pressure switches shall have contacts with differing “cut-in” and “cut-out” values. The nominal values at which differential pressure switches operate shall be fully adjustable over the whole range of the instrument and the set value shall be clearly indicated by means of a scale and pointer. Contacts of differential pressure switches shall be hermetically sealed.

502.9 FLOWMETERS

All meters shall be in accordance with ISO 4064/1.
A flow stabilizing section shall be installed directly upstream all flowmeters.

502.9.1 Electro-magnetic Flow Meters

The flowmeters shall be of electro-magnetic inductive type having a DC pulsed field with automatic zero error averaging and low power consumption. They shall have no moving or protruding parts nor cause any restriction in the flow path and be capable of setting adjustments without the need to stop the flow.

Each metering system shall comply with BS 5792 and comprise a flow sensor mounted in the pipework line and a transmitter which degree of protection is IP67, either integrally mounted or remotely located preferably within the main control panel.

The system accuracy shall be a maximum at normal operating flow with an error not more than 0.2% of the reading. When operating in the lower 30% of the meter range, the accuracy shall be within ±0.5%.

a) **Flow sensors** These shall comprise electrodes located in a meter tube which shall be of watertight construction, suitable for operation without loss of accuracy when totally submerged to a depth of 3 metres or even burried into the ground together with the water pipe. Its degree of protection shall be IP68. They will not contain any active components such as amplifiers or memory modules.

The meter tubes shall be made from a non-magnetic material lined with an inert material suitable for the medium. The flow-meter may be flanged or welded ends type. On flanged type the lining shall cover the external parts of both flanges.

The measuring electrodes shall be continuously cleaned by means which do not interrupt the process flow or the measurement. A sensing electrode shall also be provided to detect when the flow meter is not fully charged with liquid.

The flowmeter body shall be effectively bonded by non-corrodible, tinned copper braid links at each end, to the adjacent pipework to ensure a good connection between the body and the metered liquid, an earthing flange being inserted where non-conducting pipework is employed.

b) Transmitter

The transmitter shall provide the following minimum functions:

- Conversion of its supply voltage (85 to 260 VAC or 11 to 40 V DC) with galvanic separation up to 500 V in a pulsed signal which feeds the coils in the flow sensor. This method allows the transmitter to compensate for a zero drift of the flowmeter and shall give the flowmeter a perfect zero stability.

- Supervision of the flow sensor: the transmitter shall be able to generate an alarm signal when the following conditions occur:

  - ♦ water conductivity below a preset level
  - ♦ flow meter empty
  - ♦ reverse flow direction

- Output signals to inform the control/display equipment. Thus, the transmitter shall have as a minimum the following independent output signals:

- ♦ Standard analogue current signal 4-20 mA fully isolated from input and other outputs, and where the zero and full scale mA - value are configurable as well as the measuring range. The range adjustment shall be continuous, and the units shall be configurable in flow engineering units.

This analogue signal shall represent forward and reverse flows.

An output digital signal shall be provided to indicate flow direction.

Moreover, the transmitter shall provide the possibility to switch automatically to a second selected range where the flow is heavily variable; in this case an output contact shall be provided as well to indicate the selected measuring range.

- ♦ Serial port for down - loading data.

- ♦ Two pulse signals, fully configurable in volume and length. The pulse signals shall be open collector transistors or voltage free contacts.

- ♦ Two alarm signals, fully configurable and representing the following error signals (each error signal can be assigned through configuration to the first, the second or none of the two alarm contacts):

  - ∗ empty pipe
  - ∗ conductivity out of range
  - ∗ no signal from electrodes
  - ∗ coils broken (open circuit)
  - ∗ flow above or below selected alarm level
  - ∗ reverse flow direction
  - ∗ output pulse frequency above maximum selected rate.

The alarm signals shall be open collector transistors or voltage free contacts.

- – One contact input signal, used to reset the built-in flow totaliser, configurable as being enabled or disabled.

- – Local, user-friendly indicator, used to inform the operator about the measurement. The indicator shall provide at least the following information and functions:

  - ♦ actual flow with direction, in selected units
  - ♦ alarm indication with full description
  - ♦ selection of total positive, negative and net flow as well as velocity in the pipe and actual flow in percentage of full scale.

- – Configuration tool: It consists of a password protected menu from which the operator shall be able to access and set all configurable parameters grouped by function: measuring range, totalisers, alarms,..... A test function shall be available as well to test the wiring and the complete configuration.

- – Where specified, removable data storage memory, non volatile memory module (EEPROM) chip for instruments data and process data in case of replacement of the instrument.

c) Flowmeter Cabling

Where remote mounted converters are specified, cables shall be provided, installed and terminated between the sensor and converter/ pulse power unit for the following purposes:

flow signal;

reference signal;

coil supply;

Such cables and sealing glands shall be suitable for submersible operation (IP68) of the sensor to the depth specified. The length of each cable shall be as specified.

d) Spool Piece

A flanged steel pipe spool piece shall be provided of the same diameter and length as the respective flowmeter and flanged for insertion in the pipe should it be necessary to remove the flowmeter.

Isolating gate valves shall be provided on either side of the flow meter.

e) Accuracy

The accuracy of the flowmeter shall be independent of the range which has been selected for the analogue signal and shall be better than 0.2% of the actual measurement. Thus the flowmeter shall be supplied with a calibration certificate mentioning also the pressure at which the meter has been factory tested.

Note : the flow test shall be made on a recognised test bench which is traceable to international standards.

502.9.2 Differential Pressure Flowmeters

Flowmeters of the differential pressure type shall be designed and installed in compliance with an Approved Standard. Primary devices shall be carrier-ring type orifice assemblies with stainless steel orifice plate, or venturi tubes and shall include two sets of gaskets and fixing bolts for each primary device. Gasket materials shall be appropriate to the metered fluid and service conditions. Full details of orifice or venturi tube calculations shall be supplied.

An adequate filter unit shall be installed upstream the meter.

Orifices shall be square-edged and concentric. The upstream edges of orifices shall be sufficiently sharp that the reflection of a beam of light from the edge cannot be seen without magnification. Drain holes shall be provided. The diameter ratio shall be between 0.20 and 0.70. Orifice assemblies shall have identification tags showing the direction of flow, orifice diameter and position of drain hole. The identification tag shall be welded to the plate before the orifice is machined.

Insertion probe type installations shall follow equipment manufacturers recommendations. The probe shall be mounted to a standard sired ferrule or flange plate and include appropriate 3-way valve block.

Differential pressure transmitters and switches shall have over-range protection up to 1.5 times the maximum line pressure.

Location of these devices should be such that no tubulence shall interfere with the measurement of pressure either side of the device.

Signal converter - The sensor shall be of the inductive type giving an output of 4-20m a proportional and the flowrate and a totaliser. The sensor shall be protected to IP66 and having the following characteristics:

- Accuracy: <±0,25% of FSD between 25 & 100% of the flow measured.
- Stability: 6 months period: ±0,25% of FDS
- Voltage supply: 220 V AC
- Sensitivity: < 0,005%/V at 50% flow and more

502.9.3 Variable Area Flowmeters

Variable area flowmeters shall have glass or metallic tubes according to the particular application.

An adequate filter unit shall be installed upstream the meter.

Metering tubes shall be removable for range change or cleaning without disassembling the meter or removing it from the line. Metering tubes shall have ends of equal cross-sectional area and if 0 ring seals are used, tube retainer springs shall be outside the fluid stream. End fittings shall be rotatable to any angle. Connections shall be horizontal and plugged vertical openings shall be provided for cleaning purposes.

502.9.4 Ultrasonic In-line Flowmeters

The flowmeters shall have flanged steel bodies and be without probes or pressure tappings which can foul or create a disturbance to the flow. The meter performance shall not be affected by emptying of the pipeline, and servicing shall be possible without the need to remove the meter from the pipeline.

The sensor tube and associated equipment shall be capable of withstanding occasional submergence in the flowmetering chambers. The contract shall include for the provision of a 230 V 50 Hz power supply from the nearest distribution panel, and a power pack unit if required for flowmeter operation.

The converter/transmitter unit and the power pack unit shall be housed in a G.R.P. lockable cabinet which may be either pedestal or wall mounted as appropriate to the meter location. The cabinets shall have heaters and thermostats if required to prevent condensation.

The contract shall include for all internal wiring, and for cabling between the flowmeter and cabinet. Where necessary cabling shall be screened to prevent interference.
The transmitter shall give an output signal of 4-20 mA.

The span of the instrument shall be adjustable and the range of each instrument shall be chosen to unit the particular flow range. Meters shall be able to withstand surge flows above the normal operating range. Means shall be provided for check calibrating the meter on site.

The output signals from the flowmeters shall be wired back for indication, integration and recording of flows with provision for future wiring to a telemetry outstation.

Meters on gravity lines will normally have flow, and although this could be low at some times of the day, in practice flow is unlikely to drop below approximately 20% of maximum. The meters on the pumping mains will have flow dependent on the operation of the pumps.

502.9.5 Mechanical Flowmeters

Mechanical flowmeters shall be of the helix type and incorporated into a flanged section of pipe.

Tapers shall be provided, or non-standard bearings and propellers, if required, to obtain the specified degree of accuracy at the specified flow rates.

The meters shall be suitable for working pressures up to 16 bar unless otherwise stated.

An extension drive and extended head shall be fitted to meters as required. The drive shaft bearings and gears shall be designed for long life under continuous operation, and normal wear shall not significantly affect the accuracy of the meter.

Meters shall have a circular dial and rate of flow indicator registering flow in units as specified in PTSD. A flow totalizer having at least six digits shall be incorporated in the head. The totalizer shall have a capacity of at least one years flow at maximum flow rate. A multiplying factor in multiples of 10 may be used in conjunction with the totalizer if required, however if this is the case, the factor shall be clearly marked alongside the register.

The meter bodies shall be in cast iron with a high quality epoxy coatings minimum 150 microns, inside and outside.

An adequate filter unit shall be installed upstream the meter.

Meters shall be individually flow calibrated at the manufacturers works and shall be guaranteed to within ±2% of true flow within the rated range of the meter. Each meter shall be supplied with a calibration certificate.

The coupling between the wet and the dry part (totaliser mechanism) shall be magnetic, fully tamperproof against any external non destructive actions. The totaliser mechanism shall be located in a non plastic housing, preferably copper, and with a solid glass window. It shall be totally condensation free and waterproof if submersed under 2m of water.

It shall be possible to remove all moving parts from the meter without the necessity to remove the meter body from the pipeline. A blanking plate shall be provided for each meter, if necessary, to allow flow to pass through the meter body when the operating mechanism has been removed.

The spare parts shall include as a minimum spare gearing and bearings for each size of flowmeter used.

Where specified meters shall incorporate a pulsed output unit and data logger connection to enable flow rates to be monitored and transferred for plotting at a remote data port, microcomputer and printer for analysis. However, the totaliser mechanism of all meters shall be pre-equipped to receive a pulse output unit in the future which can be added on site without destroying the seal and without removing the meter or the measuring mechanism. The pulse unit and data module shall be self supporting using dry batteries.

503. PROGRAMMABLE LOGIC CONTROLLER (PLC)

503.1 DESIGN

These are microprocessor based controllers designed to suit various application needs such as controlling, regulating, monitoring, etc...

They shall be of a proven technology, shall have robust enclosures and shall provide reliable functioning even in locations near sources of electromagnetic interference.

The PLC units could be of an expandable compact or a modular type. PLCs shall cater for analogue and digital inputs/outputs and have serial ports for connection to computer equipment. They shall be capable to accommodate special modules such as intelligent peripheral cards or functional units that operate autonomously.

The PLC units shall be capable of processing complex data at high speed. For large programs, CPUs shall be added to maintain a high processing speed.

PLC shall support hierarchical configurations of control system networks with central operator station.

503.2 POWER SUPPLIES

Instrument signals shall operate at 24 VDC, derived from a suitably rated power supply to each PLC or instrument panel section and connected to the I/O terminals as necessary. The power supply units shall be sized such that the total demand does not exceed 75% of the power supply's maximum rating.

503.3 PLC SOFTWARE PROGRAMMING

The programming language shall conform to IEC 1131 part III and it could be one of the following types:

Ladder diagram
Function Chart
Instruction Set

The software development shall be done by the use of a PC for easy programming.

503.4 MEMORIES

The PLC memory management system shall include the following memory functions:

a) System memory: for basic software already programmed by the manufacturer to compile the user programs.

b) User memory: It contains the user program, the capacity of this memory shall be determined according to the application.

c) Card memory: to retain information for a specific period in case of communication failure.

503.5 COMMUNICATION PORTS

The unit (PLC) supplied shall have at least two communication ports for:

a) Connection of hand-held or portable programming and monitoring unit.

b) Connection to a data highway, telemetry system or other processors.

Item b) shall, unless for reasons of compatibility with existing systems, conform to either RS232 or RS422/RS485 standards.

The contractor shall be responsible for verifying compatibility of communication interfaces and shall provide full details of the protocols used by this system or other systems needing to communicate with it.

503.6 WATCHDOG

All PLCs shall be self monitoring and any system failure (or instrumentation failure where appropriate), whether hardware or software derived, shall cause the watchdog relay(s) to de-energise/fail-safe and uninhibit back-up control operation and/or carry out any function as detailed in the functional design specification.

Watchdog status shall be indicated visually on the panel sections and the SSU mimics.

Failure of PLCs shall not leave the associated plant in an unsafe condition or allow a process failure.

503.7 INSTALLATION

The installation of PLC units and accessories (communication couplers, modems,etc...) shall be to the manufacturer recommendations.

PLC equipment shall be mounted in secure lockable panels, which may be housed within an instrument panel.

Cables used for PLC unit supply, I/O connections and data communication bus shall be routed in a separate conduit away from any power cables.

503.8 HAND-HELD PROGRAMMING UNIT

It shall be supplied where specified in particular specifications. It shall connect to the PLC units through a communication port and shall be able of monitoring and field tuning of operational parameters as well as modifying user programs.

504. REMOTE TERMINAL UNITS

504.1 DESIGN

Remote Terminal Units (RTU) consist of a number of PLCs as described in the PLC section of the general specification.

The RTU shall transmit a digital report whenever a nominated alarm or analogue change-of-state condition occurs except when periodic interrogation/polling is taking place - then the alarm will report at end of session. The RTU receiver will support acknowledgement messages and periodic interrogation/polling from the SSU. The transceiver equipment shall be specifically designed for use in digital networks and incorporate the following features:

i) Ultra low power consumption.
ii) Sleep and Standby modes.
iii) Hardware and bit synchronisation.

Intercommunication between RTU's will be necessary if they are used as signal repeaters, or if the message handling of the radio network requires the RTU transmissions to be synchronised.

All RTU equipment shall be mounted in secure lockable panels, which may be housed within an instrument panel.

A watchdog system is required at each RTU/process area or group.

504.2 POWER SUPPLIES

RTU equipment shall operate from the specified site U.P.S., however, at locations where power is not available, then batteries charged from solar panels may be designated as the electrical supply source.

90 minutes full function battery backup including continuous battery charging equipment shall be provided for each RTU unit and the signals required for monitoring and control at 24V DC, 110V AC and any other voltage used for instrumentation.

504.3 MEMORY

The RTU unit shall have sufficient memory capacity such that in the event of a communications failure, information shall be retained for a minimum of two weeks with normal digital event/alarm density and all analogues at 15 minutes sample rate.

505. CONTROL SYSTEMS

505.1 OVERVIEW

A fully instrumented control scheme utilising distributed control systems, where particularly specified, shall be provided for monitoring, controlling and retrieving data from the plant. Sufficient instrumentation and hardware interfaces shall be installed to enable the control system to automatically control the process and provide sufficient information for the plant performance to be monitored.

The control system shall consist of a PC based, System Supervisory Unit (SSU) at a specified location (control center) and a number of remote terminal units (RTU's).

Each RTU shall be capable of autonomous operation without reference to the central computer, but shall collect and transfer plant and process data and accept control or programming information from the central computer, (ON/OFF commands, analog set points, counter index setting). Data is collected by sensors connected to the RTUs, and commands are dispatched to controlling elements also connected to the RTUs.

User facilities provided at the System Supervisory Unit shall include but are not restricted to:

- presentation of current data via VDU mimic diagrams and hard copy;
- display and acceptance of alarms;
- presentation of historical data via VDU graphics and hard copy;
- manual input of information/data (eg. operator's log, chemical analysis, etc);
- management summary reports.

Access to such facilities shall be presented in a manner which requires no programming experience.

All processes shall be Software controlled through microprocessor based controllers (PLC, ...). All plant shall be monitored through local telemetry units to display status/alarms at the SSU.

Safety, emergency and high priority signals must be independent of the software based control system. The Contractor shall review the control system at each stage of the design and provide all required inhibits.

All inhibit status shall be indicated visually, on the panel sections and SSU database/mimics and all alarm signals shall be hard-wired to annunciators.

The control system shall be designed for automatic and manual operation.

505.2 DATA ACQUISITION AND RESTITUTION OF COMMANDS

505.2.1 Data acquisition

Data acquisition depends mainly on the adopted communication protocol and the type of network (permanent links or public switched telephone network).

The computer system allows the data acquisition in real time (without time logging) or deferred time (with time logging) in a user-transparent way.

Data acquired by the Center are logic states, analog measurements, counter values, events (alarms, change-of-state), measurements or counters recording.

505.2.2 Faults and Alarms Detection

The Center detects any change-of-state which generates an alarm and the reversion to the normal state.

The Center verifies that it receives from each station significant information at a sufficient frequency. The maximum response time is configurable for each station. Should the period be exceeded an alarm shall be initiated. With query / response protocols, transmission faults could be managed as alarm triggering events.

The Center monitors the execution time of remote commands (remote On/Off commands, remote setpoints, counter index setting) where specified in the configuration : it compares the issued command to the expected result and initiates an alarm, should the discrepancy last more than the maximum specified execution time.

505.2.3 Data Restitution

The user can intervene on the process from the Center, by sending information to the local units which modify the actuators operation. These information are as follows:

- remote controls, logic type information, which allow the modification of equipment status, such as, fixed speed pumps.
- remote setpoints, analog type information, which allow the adjustment of an equipment operation variables, such as the valve position or the speed of a variable speed pump.
- remote values, digital type information, which allow the modification of the counter index setting or the transmission of any value used by the local unit during its operation (e.g. a coefficient).

505.3 SYSTEM PERFORMANCE

The system must be capable of accommodating the full Input/Output configuration including all options with spare I/O per outstation of 20%. In this fully expanded mode the following performance figures shall apply:

a) VDU mimic update and regeneration - 10 secs max.

b) Maximum time from field alarm or status event (eg. contact closing) to report on printer/VDU shall be 20 seconds.

c) Maximum time from completing a request to change an output to the output activating shall be 20 seconds.

505.4 POWER FAILURES/BACK-UP/RESTART

In the event of power failure, the entire system of control centre and distributed outstations shall restart automatically upon resumption of the supply. By a series of interrogative commands, the outstations shall determine the position in the cycle which the process had reached at the instant of interruption and shall resume control at an agreed point.

The central computer shall have an uninterruptible power supply to enable the components defined in the Particular Specifications to function properly during a power supply failure of 30 minutes unless otherwise specified.

Memories for outstation plcs shall be provided with battery back-up facilities for the same duration or as otherwise specified.

505.5 OPERATIONAL CONSIDERATIONS

System users and control room operators must not be expected, or need, to have other than a superficial knowledge of computer usage.

The main methods of operator access will be via qwerty-based keyboard(s) and cursor control device (mouse) with which to point and select commands.

Operator facilities shall be available to the user in menu format. The need for the normal operational user to access the host computer's operating system shall be avoided in day to day operation.

505.6 EXPANSION

The system shall be designed to allow for expansion. The ultimate capability of the system shall not be constrained by the initially installed hardware and software.

As a minimum, expansion should be allowed for in the following areas:

a) Number of RTU's to be addressed and polled
b) Number and type of points to be defined, addressed and polled
c) Range of functions to be processed
d) Number and type of peripherals to be driven
e) Amount of memory to be addressed
f) Ability to expand the control output functions of the system as a whole without reference to the Vendor for sophisticated equipment, licences, etc.

505.7 RELIABILITY

The system hardware and software shall demonstrate a high level of reliability.

The application software shall prevent the input of illegal or undefined commands, prevent system lock up and have a constantly available recovery mechanism for the user.

A key design principle must be that of graceful degradation, with the ability to maintain the maximum degree of control for the maximum time under fault conditions. The loss of facilities should, as far as possible, be isolated on the principle of damage containment and shall fail in the safe mode at all times.

505.8 OPERATING PARAMETERS

Initially the system will be operated with the operating parameters being fixed on a first estimate basis, but as information is accumulated these operating parameters will be fine tuned. All operating parameters shall be software controlled and are identified in the text by 'OP'.

505.9 PROCESS AREAS

For control purposes, the works shall be sub-divided into process areas by the Contractor, typically as indicated in the Particular Specifications.

These areas shall not necessarily be the locations of the RTU's. It may be possible to use a single outstation to control and monitor a number of areas; alternatively, more than one RTU may be required for a particular area.

Instrumentation, motor starters, actuators and electrically operated items of equipment shall be connected to each RTU as appropriate, which shall control and monitor its process area without reference to the SSU. Therefore the system software shall reside for each area in the RTU's but changes of control operating parameters shall be possible only from the SSU (under normal conditions). All plant data shall be routed to the SSU through the RTU's via either a radial or loop configuration depending upon the relative suitability of the equipment being offered. This data highway may be hardwired, fibre optic or radio based.

Process data between area RTU's shall continue uninterrupted in the event of an SSU failure. Should the SSU fail or the RTU/SSU link break, the RTU shall be able to continue to control the plant area using the last operating parameters settings/process data until the link is restored or the OP's are changed with a portable unit.

In the event of the RTU failing the watchdog systems under each process area shall operate.

505.10 ORGANIZATION

The operator shall locate each datum geographically through a hierarchical structure consisting of a ″network″, a ″front end processor″, a ″station″, and a ″channel″.

505.10.1 Network

A network is constituted by the local units communicating with the center via one same asynchronous serial line. Local units in one network have the same communication protocol.

However, different networks may support different protocols. The computer system shall support, as a minimum, the number of networks specified in the Particular Technical Specifications Document.

505.10.2 Front end processor

A front end processor manages communications with PLC's or transmitters, is compatible with and can support all communication links.

Data exchange between the front end processor or the station and the Center is governed by a communication protocol. The software shall be designed to allow for the installation of new protocols.

505.10.3 Station

The available data block in a front end processor may be sub-divided into ″stations″ representing either a functional unit or a particular local unit (RTU). This subdivision allows the system query with selection criteria.

505.10.4 Channel

A channel is a logic, analog or digital input or output. There are six types of channels.

- a signalling : logic input
- a command : logic output
- a measurement : analog input
- a counter value : digital input
- a setting : digital output.

505.11 MANAGEMENT REPORTS

An essential part of the monitoring mode shall be the production of management reports, for which data processing will be carried out at the SSU. The logging interval and signal value, instantaneous or average over the logging period, will be determined by the management report requirements.

505.12 COMPLIANCE WITH SPECIFICATION AND STANDARDS

The following documents shall be used and complied within the design and installation of the control system and instrumentation:

a) IEE - Guidelines for the documentation of computer software,

b) BS 6739 - Instrumentation in process control systems,

c) The relevant European or International Standard shall be used for any item, installation or application.

d) ISO 9000 standards.

Where a particular specification has been identified in a detailed clause it shall be complied with in conjunction with the above. Any contradictions found should be notified to the Engineer.

505.13 TRAINING

The Contract shall include for the training of the Purchaser's staff in the operation and maintenance of the system.

This shall take the form of a structured training programme and shall include the costs of all course materials.

Details shall be provided in the Schedule of Particulars of the training facilities offered.

The following aspects shall be included:

On-Line Training: Using built-in simulators with plant operational or non-operational.
Off-Line Training: Using off-line simulators.

Documentation: The provision of high quality documentation for training giving explicit and easy to understand step-by-step procedures, with explanatory diagrams, flowcharts and examples.

506. SYSTEM HARDWARE

506.1 DESIGN

The System Supervisory Unit shall incorporate microprocessor based units of suitable operating and storage capacity to provide the specified data handling, processing and graphics performance and having non volatile or on-board battery supported RAM and hard disk data storage capacity together with dual drive 3.5" 1.4 megabyte floppy disk drives, tape streamer, CD drive, 4 serial and 2 parallel ports. The disk operating system shall be provided with full documentation and spare copy. Full auto-restart after power failure is required, without manual intervention.

Hard disk data archive capacity shall be sufficient for 180 days on line availability at least. Each day over 180 days, the oldest data shall be overwritten by the latest information automatically. Both RAM and hard disk shall have 100% spare capacity in excess of max working load to allow for system development in the future.

The computer, hard disk, floppy disk and tape streamer shall be supplied in one integral unit. All devices shall be easily accessible from the front of the supervisory unit.

506.2 VISUAL DISPLAY UNITS

VDU's shall be 21 inch SVGA colour monitor screens in an anti-glare finish enclosure, matching that of the computer system supplied. The VDU shall have a frequency range suitable for the computer system supplied and shall be capable of displaying information in alpha-numeric and graphic form from a minimum of eight foreground and background colours. Characters shall be legibly and stably displayed. The unit shall include all necessary adjustable picture controls to adjust the image.

506.3 KEYBOARDS

Keyboards shall be a low profile standard QWERTY pattern, complete with all necessary special function keys. The function keys shall be clearly labelled with any symbols or descriptions necessary, and those dedicated for reconfiguration shall be supplied with means of preventing unauthorised operation. The keyboard shall be a separate, free standing unit suitable for desk top mounting and shall have an ergonomical form design.

506.4 PRINTERS

Printers shall be robust and designed for continuous duty, capable of supporting alphanumeric and graphic output and shall be fully compatible with the character and graphic sets of the computer system supplied. Both serial (RS232) and Centronics parallel interfaces shall be supplied, along with a minimum printer buffer size of 2 Mb. The printer shall offer both tractor and single sheet paper feeds without user modification. Text character printers for status report logging and alarm logging shall be at least 25 pin dot matrix pattern. They shall print in black with alarm messages in red at a speed of at least 150 ch/s (NLQ) on A4 size, fan-folded paper collected in a paper tray.

Colour graphics printers shall have A4 media size capability, with manual feed of cut-sheet paper and film or sprocket feed of 2-fold paper. The printer shall be a thermal inkjet drop-on-demand type having a graphics resolution of 600 x 600 dpi and near-letter quality (NLQ) text printout of 234 characters per second at 10 pitch. Graphics print speed on paper should be 0.5 minute or less and 1 minute or less on film.

Print cartridges shall be interchangeable to allow both colour and black printouts and the software shall permit a choice of font types and sizes including Roman, Letter Gothic and Courier with between 8-12 pitch print size.

506.5 MODEMS

Modems shall conform to Bell or CCITT standards. They shall provide full support to Data Terminating Equipment. Modems could be rack mounted type or stand alone type and shall have the following characteristics:

- External power supply: 220V AC
- Operating conditions: -5 °C to 55 °C
- Microprocessor based
- High data communication rate
- Synchronous/Asynchronous operation
- Data compression
- Error detection and correction
- Full and half duplex operation
- Data format: serial, binary
- Serial data interface: RS 232 unless otherwise specified
- Remote configuration capability through the network management system
- Automatic feature negotiation that selects the best combination of speed, error control and data compression.
- Password and callback security to control unauthorized access to attached Data Terminal Equipment
- Front panel password
- Help screens and visual indicators
- Diagnostics: Local digital and analogue loopback, remote digital loopback
- At - Command Set - support
- Volume controlled speaker
- Non volatile memory for the storage of configurations

Line modems shall support tone and pulse dialing and have an auto answer capability and hang-up control via the RS 232 interface. They shall support switched modem carriers for remote applications. The transmit level shall be maximum -9 dBm or as required by the PTT. The receiver sensitivity shall be -43 dBm.
Radio modems shall be of an integrated unit type (digital data modem with a radio transceiver).

506.6 MIMIC PANEL

The mimic panel allows the supervisor to have a global view of the installation configuration and the states of the various components represented by symbolic schematics.

It shall be an engraved panel, a relief panel or a panel with a painted front side.

506.6.1 Engraved Panel

In this type of panels, the front side shall be made of methacrylate (Plexiglas), and shall be smooth, polished, translucent and varnished or mechanically polished to prevent reflection.

Engraving and paint shall be performed on the rear side.

The front side shall be completely smooth showing no unevenness. However, it is possible to slot signalling lamps and operating devices into the front side.

Each unit shall have a maximum size of 3000 x 1400 mm. For larger surfaces, the panel shall consist of several modular units.

Panels shall have fitted inside, the front side and the rear, a polyester tracing design representing the circuit identification charts to facilitate any future modification.

The signalling system shall be placed on the rear side with or without a plexi rear supporting plate and may comprise: continuous tracks, dot lights of different shapes, lighting surfaces, and the animation system.

It is possible to use the 3 following signalling types:
- MLD lamps (multileds)
- Incandescent lamps
- Fluorescent tubes located in a box at the rear side, for lighting the whole panel.

506.6.2 Panel with a front side or relief panel

The front side of these panels shall consist of plastic or metal elements.

a) Plastic elements shall be fixed on a checkered base, a painted sheet, or a methacrylate surface,...

   Following are the materials to be used:

   - Painted ABS, thickness 2 mm
   - Painted PVC, thickness 5/10 mm self adhesive according to a chart of colours or samples.
   - METHACRYLATE (Plexiglas, perspex, altuglass, etc,..) thickness 3 mm, tinted according to the manufacturer’s schedule of colours.

   The fixing shall be carried out:

   - on checkered and methacrylate base,
   - through a chemical reaction
   - on sheet with adequate binding agents absorbing the differences due to the materials expansions.

b) Metal parts shall only be fixed on sheet bases. Anodized painted aluminium or chromium brass (thickness 3 or 4 mm) shall be used. These elements shall be bolted to the front side.

In either cases, the modification shall be carried out on site; the signalling system shall consist of flooding lamps with light transmission tube made of methacrylate.

The lighting type shall be multiled or incandescent.

506.6.3 Panel with a painted front side

The front side shall be executed on a checkered or painted sheet or methacrylate surface. This technique is suitable for panels with inserted operation and control devices. The front side may be polished, glazed or mat by applying a scratch-proof varnish, ensuring an excellent protection.

The signalling system shall be identical to that described above. The panel shall comprise all devices and main conduits of the installation. It shall be entirely painted according to the project submitted before execution to the Engineer for approval. Each motor shall be represented by a red signalling lamp showing its operation. This signalling lamp shall flicker in case of thermal fault.

Lamp test button shall be installed as well.

507. SCADA SYSTEM

507.1 MODES AND FUNCTIONS

The complete software package shall enable the system to function in accordance with the Functional Design Specification (FDS) and allow for the addition of future software tasks (e.g. monitoring of other process parameters) as and when required. The software shall therefore be written in a structured manner with a core of control routines that can be accessed by additional programme routines without having to rewrite the basic process control software.

507.2 ENVIRONMENT

The software conforms with the current main standards and uses the following packages:

- operating system
- database management system
- spread sheet
- graphic library
- graphic package.

The software is an OPEN system since it shall include a real-time acquisition database, thus allowing other applications (mathematic models, leakage detection, etc ...) to easily retrieve stored data and carry out very specific processings.

The software shall include an independent utility program running under DOS (UNIX) designed to convert stored data into a compact format such as a text or compatible formats with other packages such as EXCEL, ACCESS, etc ...

This utility program shall allow to sort data according to the following selection criteria:

- source station
- variable type : logic, analog, counter
- variable number
- date and time specifying the beginning and the end of a period.

Sorted data only are converted into the selected format.

This utility program shall not be run on the computer used for supervision. However, it can co-exist with the configuration function and other packages, especially those allowing to exploit the stored data.

The system includes all ETHERNET software layers and allows distributed Client / Server architectures.

Moreover, such system can be run under Windows (latest version) allowing operators to open simultaneously Windows work sessions (Excel, Word, ...).

The operating system being the latest version of DOS or UNIX or other approved O.S.

507.3 SYSTEM SECURITY

Security of the system shall be provided by allocation of passwords and varying degrees of privilege (eg. operator, supervisor, system engineer/manager). By default, there is no password. The configuration software allows to create a password by selecting the corresponding item within the Edit menu. The selection box will then open, showing the passwords various access levels and their respective poke points. The selection of a level shall open a dialogue box which will prompt the user to input the correct password. Passwords shall also be required before deletion of data or other operator actions which may cause serious malfunction or loss of data by inadvertent action required for a managerial function. Any successful or unsuccessful change in security level shall be logged. Passwords shall be blanked on the screen during entry, and should be confirmed for validation.

The software shall be capable of providing at least three levels of operation:

1) for operations personnel to monitor and control the plant (where applicable);

2) for the supervisor to change parameters

3) to enable a designated engineer to modify or add new sequence programmes or run diagnostic programmes. These procedures shall be carried out with the minimum disruption to the system.

Supervisors and Engineer's mode shall be selectable only after a unique password/key system has been satisfied for each user.

507.4 DATA PROCESSING

The basic processing of acquired data carried out by the system software (or Telemanagement Center) will provide the operators and managers with elaborated information, and generate information calculated from the acquired data.

507.4.1 Measurements

Following are the various basic processings of measurements:

- Correctness check
- Conversion
- Threshold detection
- Minima and maxima management
- Inhibition.

- <u>Correctness check</u>

  The purpose of correctness checks is to verify that the measurement signal generated by standard output sensors (4-20 mA or 0-20 mA) is within the expected range, otherwise an alarm will be initiated and the measurement value frozen.

– Conversion

The value of a measurement sent by a PLC or an RTU shall be converted into a real value in terms of the configured maximum and minimum of the scale and the adopted resolution.

Consequently, a conversion formula shall be applied to each measurement to deduce the data real value. This configuration allows the establishment of simple as well as very complex conversion formulas.

– Threshold detection

Each measurement shall have a high and a low configured threshold. A dead band, adjustable around each threshold's theoretical value ensures a hysteresis to stabilize the detection of the threshold overstepping. Each threshold can have three configured detection modes:

– No detection
– Threshold overstepping (high or low)
– Overstepping of a high threshold and a low threshold.
– Absolute Minima and Maxima

At each data acquisition, the value of a measurement is compared to the minimal and maximal values recorded during previous data acquisitions. If the threshold is overstepped the minimum or maximum is updated.

– Inhibition

A measurement can be inhibited by means of a logic input. When the logic input is active, the measurement shall not be further processed and the value of the relevant channel will be frozen (ex : inhibition of a measurement due to a sensor failure). Declaring a measurement ″out of operation″ shall have the same effect as inhibition.

507.4.2 Setpoints

Setpoints and analog measurements have identical descriptors. Setpoints basic processings are the following:

– Execution control
– Inhibition.

– Execution control

Once a setpoint is modified, and received by the front end processor, the Center shall control that the absolute value of the setpoint deviation in comparison with the associated adjusted variable becomes, after a configurable time, inferior to a configurable value; otherwise an alarm shall be initiated.

However, to prevent any disturbance to the operation of the adjusted equipment, the operator cannot modify a setpoint having an increment superior to a configured value (″hysteresis setpoint″).

– Inhibition

A setpoint can be inhibited by a logic input. When the latter is active, the setpoint cannot be transmitted to the local units.

507.4.3 Signalling

A signalling is a logic input; it could be a simple signalling, an alarm or an internal logic calculation.

The basic processings of logic information are:

– Operating time counting
– Status counting
– Inhibition.

– Operating time counting

An operating time counter can be associated to a real-time acquired logic input channel, to allow the calculation of the equipment operating time (ex: running time of a pump). The sampling period of the related channel status is configurable to 60, 180, 300 or 900 seconds or more.

– Status counting

A change-of-state counter can be associated to a real-time acquired logic input channel. According to the configuration, the counter determines :

– the number of passages to the active state
– the number of passages to the non-active state
– the number of changes-of-state.

Such a counter can be reset periodically or not; at hourly, daily or weekly intervals. The counter value shall be printed prior to any reset.

– Inhibition

An input channel can be inhibited by another logic information. When the latter is active, the data shall not be further processed.

The operator can, as well, inhibit the logic channel by declaring it ″out of operation″.

507.4.4 Counters

Digital information shall be subject to the following basic processings :

– Conversion
– Detection of alarm values
– Inhibition.

– Conversion

The acquired real value of a counter can be calculated by applying the following formula:

$$\text{Counter value} = (\text{acquired value} \times \text{coefficient}) + \text{Initial value}$$

The initial value and the coefficient are user configurable.

– Detection of alarm values

An alarm value can be associated to each counter. When this value is reached, an alarm is initiated and the message edited on the selected peripherals. For operation time counting, the message is re-edited daily until another threshold is set by the operator. This processing indicates after a configurable operation time the need for maintenance.

– Inhibition

A counter can be inhibited by a logic input channel. When the latter is active, the counter shall receive no further processing. Its value is frozen. The operator can also inhibit the counter by declaring it ″out of operation″.

507.4.5 Calculation

A data can be calculated from one to eight acquired or already calculated data, of whatever type (logic, analog, digital). The available calculation operations are : the four basic operations (+, –, ×, ÷) and the integral. The calculation period of each formula can be parameterized at 15, 30, 60, 120, 300, 900 seconds or more. Each result can be of whatever type and have a channel record like the acquired data.

Thus, calculation results can be subject to the same processings as the data (including storage).

N.B.: Integrals can be computed at an hourly, daily or weekly interval, and be reset at the end of the interval.

507.5 DATA STORAGE

All data shall be stored on the PC’s hard disk drives. Data required for management reports shall be copied onto floppy disks on a selectable, regular basis and logged as an event and indicated to the operator.

The whole system shall be backed-up on to the tape streamer in a similar manner.

Acquired data, calculation results and historical events are stored in a relational database to allow for consultation and on line processing, or transfer to other systems (ex : Excel spread sheet under windows).

507.5.1 Values storage

The system can store the values acquired in real or deferred time. Stored values are either logic states, analog or digital values.

Analog and digital values are stored, periodically, or incrementally according to the evolution of processed values, or through data files in the event of a local storage in the PLC or the local data acquisition unit. The incremental mode activates the storage of a data if the latter has varied of a configurable minimal increment, and allows the sampling at variable time intervals.

The new state of logic values is stored at each change of state.

Each stored record includes the following data:

- data reference
- date
- data value (in real units)
- data status (valid, invalid).

Storage time, which is operator configurable and could reach 13 months on line, depends mainly upon the number of stored data, the storage frequency and the disk available free space.

The user can have access to database files for data query, specific reports, etc ... by using the database standard query language. He could also have access to the files to execute configured production reports, or draw curves on a colour graphic screen. Utility programs can also copy data on an ASCII format file and use them via standard spread sheet (EXCEL, LOTUS, ...).

507.5.2 Events storage

The software creates on the hard disk a daily log file where detected events (change-of-state, threshold overstepping, fault, ...) are saved as they are received regardless of their type. The relevant variable configuration shall determine whether to store a certain datum or not. Stored data are time-logged. A file comprising the local database is automatically associated to each daily log file in order to store the configuration parameters of the same day which shall be used in processing the stored data.

Following are the various types of data that could be stored:

- on/off events (change-of-states, appearance & disappearance of alarms)
- samples of analog values (recordings of measurements transmitted in deferred time, instantaneous images transmitted regularly in real time or analog events)
- counter readings.

The storage time is conditional upon the size of the hard disk and the volume of data to be stored daily. It is a constant, expressed in days, and may be modified within certain limits. Outdated files (storage and database) are purged automatically upon expiry of the storage period. Such files may be stored on diskettes for future use.

507.5.3 Saving/Retrieval

Saving consists in copying on external magnetic support (floppy disk or magnetic tape) relevant data.

The files of the configuration database (description of data, mimics, curves, menus, logs, events, ...) and those of the storage database can be saved upon request.

507.6 USER INTERFACE

The operator communicates with the system to configure his application, consult data in real or deferred time, monitor the evolution of some data, command the printing or saving of other data, transmit remote commands, setpoints or values. Such interface is done through an operator dialog allowing a simple and quick access to the selected functionality.

The user dialog includes:

- pull down menus
- dialogs with:
  - acquisition lines
  - file selection boxes with scroll bars
  - poke points (such as push-buttons)
  - check boxes (such as in a form)
  - option buttons (such as mutual exclusion keyboards)
  - confirmation, information or error message boxes
  - standard use of the keyboard and mouse.

The status line is reserved for permanent display of the following:

- information on the communication with the front end processor (brief analysis of the protocol)
- availability of printer
- availability of hard disk
- availability of modem
- number of unacknowledged alarms (present or disappeared)
- number of unacknowledged ″stations″ faults (present or disappeared)
- number of present and unacknowledged ″remote commands″ faults
- a normal operation indicator (number of running tasks, flickering in normal operation)

Time, date and available free memory are displayed permanently.

There are three access levels corresponding to three levels of responsibilities from higher to lower: ″configuration″, ″remote control″, and ″consultation″.

The 2 higher levels are protected by a password. The access to a level entitles the access to the lower level. For example, the access to the ″configuration″ level gives access to both ″remote control″ and ″consultation″ levels. Password protection is a configuration option.

Following are the three responsibility levels that can be protected by passwords:

- administrator (System engineer).
- supervisor.
- duty staff (operator).

The administrator sets up the system configuration, back-up, extension, and the operator mode configuration.

The supervisor controls and monitors the installation through the supervisors menus configured by the administrator. It is possible to define several supervisors, having each access to a different function.

The main work of the duty staff (operator) is to be aware of, and acknowledge alarms.

507.6.1 Administrator (functions accessible at the ″configuration″ level)

The administrator sets up the system's configuration and monitors the evolution of the application. He prepares especially the operator mode, i.e. the system usual management organization.

The application configuration informs the descriptors of each elementary information. A descriptor allows the location and the definition of an information characteristics and required processing.

Elementary data may be defined from the data configuration, namely:

- networks
- slaves
- stations
- analog data
- digital data
- logic data.

Descriptors are stored in the configuration database files. Such function allows, especially, the programming of internal calculations carried out from other data, and the definition of the type of work of each peripheral connected to the Center (continuous printing, reports, log).

Upon the complete configuration of the application, the administrator can, during the system usual management, modify on line all the configuration parameters of one or a set of information. Such modifications are taken into account immediately by the system and can be recorded on the on-line printer.

The application should be re-run only to take into account any added or deleted data.

The administrator is also responsible for the definition of the menus nesting in the supervisor mode, and the configuration of logs, menus, reports, ... put at the disposal of the supervisor for the network operation.

All functions accessible at the ″remote control″ level are obviously accessible at the ″configuration″ level. The operator authorized to this level can also create or modify on line, that is, when the other tasks of the application are running, the configuration parameters of the local database. The supervisor can carry out only minor modifications of this database (ex : during start-up or changing of password). He can exit to the operating system (DOS or UNIX) without quitting the application to execute commands under DOS or UNIX i.e. delete files or formatting diskettes.

507.6.2 Supervisor (functions accessible at the ″remote control″ level)

The supervisor is the daily user of the system: the user interface allows him to pilot his installation from the menu appearing on the screen, by simply using the mouse or the keyboard.

The supervisor having access to the ″remote control″ level can have access to all functions determined in the ″consultation″ level. He can also send remote ON/OFF commands, setpoints, and commands for counter index setting. One message can hold several commands of the same type issued to the same station.

507.6.2.1 Consultation

The system consultation allows the supervisor to have either access to the instantaneous values of a number of information or to follow the evolution of several data in the form of logs or menus.

Data query may be pre-programmed by the administrator and configured in the consultation menu or specifically formulated by the supervisor through selection criteria (by function, station, channel ...).

507.6.2.2 Alarms

The supervisor can request the selected list for each duty staff area :

- of all alarms
- of present and not acknowledged alarms
- of present and acknowledged alarms
- of absent and not acknowledged alarms
- of current duty staff calls.

Alarms are acknowledged one after the other or simultaneously for a same area. Acknowledgment is recorded on an on-line printer.

507.6.2.3 Events

The call of the events dialog box allows to search for events stored in the daily files present on the hard disk according to different selection criteria (a station mnemonic, number of the channel, type of event, hours and dates of search, ...). Search result may be displayed on screen or printed. This command allows a simple and quick analysis of occurring faults.

507.6.2.4 Maintenance

The list of machines and equipment requiring maintenance and their operation time list provide maintenance personnel with necessary information for maintenance and future replacements.

A maintenance log is edited automatically if one, or several equipment operation time has overstepped the configured alarm value.

507.6.2.5 Remote management

Remote management consists in sending, to Local Units, remote commands, setpoints or values. Commands are sent either directly from a colour graphic mimic by selecting with the mouse the relevant equipment (with or without confirmation request as configured at the time of the image definition) or from the keyboard of the console. Therefore, the request to send an information displays a pop-up dialog box and the supervisor shall fill in the references and the relevant instruction value.

The Center controls the execution of remote commands or setpoints regardless of the mode used for sending commands. If the instruction is not correctly executed, an alarm message is generated and recorded on the on-line printer.

507.6.2.6 Exploitation of stored data

Following are the required basic operations:

- size of the database files
- general status (list of stored data)
- status of each station
- stored values for a datum between two dates.

Such operations are executed by using the standard tools of a database; this allows the supervisor to create specific reports.

507.6.3 Duty-staff (functions accessible at the ″consultation″ level)

This user is authorized only to consult the different data types gathered in the following lists or pages:

- list of stations (PLC’s or transmitters) with the indication of their status (not in use, not initialized, normal, fault)

- list of stations data points (or variables) with the indication of the last received time-logged value

- list of alarms: present and not acknowledged, and disappeared and not acknowledged

- list of running commands with a fault signal in case the normal delay limit is exceeded

- log of events

- page of data, configured upon request, holding information sent by different stations (i.e. a page gathering all the reservoirs levels of a network).

The ″consultation″ level allows the acknowledgement of alarms, stations faults (prolonged absence of communication) and faults in the execution of commands.

For each of the above-mentioned, and regardless of the selected view, a highlighted indication of the number of faults or unacknowledged alarms shall be displayed in the status line.

The duty staff can also consult stations to refresh data upon request. It is possible to query in a same station, all the variables, a block of variables or an isolated variable.

This level authorizes such agent to consult stored data, and save storage files and related configuration files on floppy disks. Stored data can be consulted by selecting a station, a variable and a date. The list of time-logged values can be printed upon request.

507.7 DUTY STAFF

Outside normal working hours, and in the major part of the installation, there are no supervisors in the Center. Major failures which might endanger the operation of installations are reported to the duty staff who shall act according to the notified instruction. Notification of duty staff is through the telephone (public switched telephone network and/or mobile phone).

507.7.1 Duty staff management

This function consists in transmitting to the duty staff processed data from the Center at the occurrence of determined events, such as major faults in terms of:

– date and hour of alarm appearance
– geographical area of alarm.

Information used to reach duty staff are held in a duty staff database configured by the administrator and including the following information:

– a table including, for each described area, a label, description of the area, datum references for inhibiting the duty staff function.

– a monthly schedule for each duty staff area consisting of 31 daily sheets, each having distinct hourly periods; each period being associated to a different duty staff

– a log describing the teams of duty staff; each staff may consist of several agents.

– a log describing the agents shall include:
  - name of agent
  - communication link
  - telephone number
  - deferred duty staff option.

The schedule is set for a one month period and is automatically reapplied if no modification occurs.

Upon appearance of an alarm requiring a duty staff, the Center consults the schedule to verify whether it is a duty staff period. In this case, the system locates the area and the relevant on-call duty staff. The first agent is called, and then the others, should the call remain unanswered. Each call attempt is printed out and stored in the events file.

If the system fails to reach the entire team on duty, the call is repeated after a preset time. Such call can be deferred according to the alarm importance and time of appearance.

507.7.2 Remote consultation

During a duty staff call, any supervisor aware of the access code can consult the system data remotely through a remote terminal with an autodialing modem. The interface is identical to that obtained when locally connected to the system console.

507.8 CONFIGURATION FUNCTIONS

Configuration shall use an independent software running under DOS, WINDOWS or UNIX on a desktop or a laptop computer which allows to set parameters for the supervision of a determined application. As in the supervision, the user interface uses pull down menus, dialog boxes and the mouse.

Such software is usually used by the author of the application and not the supervisors.

Configuration parameters, as well as the values of logic, analog and counter variables constitute the resident database of the application. This database is stored in a file, then loaded in the central memory as supervision instructions are launched. Variable values are set by default. It is of utmost priority to save such file.

507.8.1 Creation of a library of labels

The software includes a library of standard labels:

- name of parameters (″level″, ″flow″, ...)
- common names of machines (″pump″, ″valve″, ...)
- name of measurement units (″m″, ″m^3″, ″m^3/h″, ″ppm″, ...)
- status qualifiers (″On″, ″off″, ″fault″, ...)
- paragraph delimiters (″****″,″----″,″______″,″....″).

Every user can customize such library by creating new labels or modifying the existing ones. Labels, except for paragraph delimiters can be modified. A label cannot be destroyed. The labels are classified and listed according to the ASCII characters order.

Every user can create his own library of labels.

507.8.2 System parameter setting

The system parameters are data which mainly describe the interface between the Center and the network. They depend greatly on the protocol. They describe mainly the characteristics of the asynchronous serial link with the front end processor.

507.8.3 Creation of pages

Pages can be created by giving them a name that shall be used during the configuration of the variables in order to indicate the pages where they could be displayed. Hence, it is possible to create a page named “RESERVOIRS LEVELS” where shall be listed all the latest acquired values of the reservoirs levels.

507.8.4 Creation of stations

The creation of a station consists in identifying it with a label to which is associated an identification number dependent on the adopted protocol, and defining some of its general parameters such as the analog - to - digital conversion resolution.

The user/supervisor shall be guided by two dialog boxes:

- the list box holding the alphabetical list of all created stations
- the edit box or the modification box of the station description.

By just executing the above-mentioned operation, the created station will remain empty unless all the constituent variables are described.

Creating first all stations in a network and then describing their respective variables shall be possible. This seemingly natural method - since it describes first the network - is not the most judicious, however, because the configuration allows the duplication of a station along with all the described variables. In fact, an installation consists often of stations of limited types; all stations of a given type being identical or very similar. The best procedure is to describe wholly the most representative station of each type and its variables, then duplicate it, and enter the eventual modifications on a case by case basis.

The list dialog box allows to delete a station with all its variables, end the dialog of variables creation by going back to the main menu, and activate the variables configuration dialog of the selected station.

507.8.5 Configuration of the variables of a station

The dialog of the configuration of variables of a station complies with the same principles as that of stations, and has a similar ergonomy. As mentioned in the previous paragraph, the user is guided by dialog boxes: a list box and secondary boxes.

The list box contains the list of all variables created in the station. The user shall set up the list to his discretion: paragraph titles and delimiters (asterisks line, simple line, double line, broken line, etc ...). The other functions of the list box are:

- creation of titles and delimiters
- creation of logic variables
- creation of analog variables
- creation of counter variables
- modification of the variable
- destruction of the variable, the title or the indexed delimiter
- closing the dialog box of dialogs configuration and return to the main dialog box of the creation of stations.

507.9 COPYRIGHT AND PRODUCT SUPPORT

The copyright of software specially developed for the control system shall become the property of the Purchaser on handover of the equipment.

The Contractor shall ensure that for software of a standard nature, product support shall be available for a period of ten years from the date of supply, and submit details of the various grades of maintenance contract which he can offer for both software and hardware. These shall include the approximate costs of the supply of updates of standard software which will run on the system, as well as enhancements and improvements to specialist system software.

The Contractor shall be able to offer for demonstration an operational system, whose configuration is similar to the requirements of this system, which utilises software programmed by the Contractor's staff in-house personnel.

507.10 PROGRAMMING

Programmes shall be based on approved structured techniques using a high level language capable of accepting alterations and additions easily.

All programmes shall be tidy in format, logical to follow and be accompanied by flow diagrams. Programmes shall be extensively annotated with comments and be self-documenting.

507.11 PROGRAM DOCUMENTATION

The Contractor shall supply the following documentation:

1. Full programme listing (including all comment/remark text)
2. Complete set of flow charts
3. Diagnostic programmes
4. Operation/instruction manual for this particular project.

507.12 DIAGNOSTIC ROUTINES

The system shall be complete with a set of diagnostic routines to enable maintenance personnel to fault-find on the equipment.

The routines offered will depend upon the system supplied, but shall contain or expand on the following:

a) A routine to enable all interface cards or devices to be checked for faults or malfunctions, particularly input and output cards.
b) A routine for testing individual control loops.
c) A programme to send dummy information to the various input/output gates to test action of circuits.
d) All routines shall be available only in the “engineer's mode”.

The integrity of all plant operations must be protected at all times, therefore diagnostic programmes will require additional security when switching outputs.

508. INFORMATION PRESENTATION

508.1 DISPLAY

The visual display unit (VDU) shall be capable of displaying mimic, graphical and alpha-numeric information. Mimic diagrams shall show all relevant plant status and alarm information along with process and analytical data, e.g. flows, levels. All such data shall be updated at regular intervals, chosen to suit the rate of change of data.

The mimic diagrams shall be capable of being easily developed and modified to include changes at a later date. The diagrams shall be clearly presented so that the operator may readily assimilate the information contained therein. Diagrams shall be nested at several levels to enable the operator to obtain detailed information quickly and yet retain an overview of a complete area of the plant.

Status information shall be updated as the change takes place and parameters which are out of limits shall initiate an alarm sequence.

Alarm messages shall be displayed on a dedicated section of the VDU screen, which shall be available at all times.

Displays shall be organised into a hierarchical structure, ranging from an overview down to individual detailed RTU displays. The displays shall be user definable and details of the building/modifications package shall be provided. A real time clock shall be included on all displays giving both time and date. Hard copies of screen displays will therefore always show time or events being portrayed. In the case of a management report covering a time period, any hard copy taken within that period will clearly show the point of retrieval.

When an RTU is called up on the VDU mimic display, analogue values and the status of all units shall be displayed, ie. running, failed, open, closed, full, empty, flowing, etc.

508.2 COLOURS

Colours and layouts of the mimic diagrams shall be established during discussion with the Engineer during the development phase of the software.

The minimum requirements are sixteen colours, with 'blinking' facilities.

The colours shall be consistent with the VGA 16 colour choice and allocated for plant contents and flow lines as follows and where appropriate.

a) Process Colours

Colour	Water Treatment	Sewage Treatment
Black	Background	Background
Green	Raw Water	Raw sewage
Light Green	Gas (Chlorine)	Settled sewage Liquor/Storm tanks Lagoon outflow
Cyan	Filtered, well or backwash water	-
Light Cyan	-	-
Brown	Dirty water	Raw sludge Screenings Disposal
Yellow	Gas (SO_2)	Gas (Methane)
Red	-	-
Light Red	-	-
Magenta	Gas (NH_3)	Activated sludge
Light Magenta	-	-
Grey	-	Treated sludge
Light grey	-	-
White	Air	Air
Light Blue	-	-
Blue	Potable water	Final effluent

Colours which are not defined above may be otherwise allocated to the approval of the Engineer.

Plant icons shall be : Running/open/on - Process colour (see above)
Stopped/closed/off - Light Grey

Alarms (potential danger to personnel/major failure of plant/process)	Red
Faults (Motor tripped etc)	Yellow

b) Text

Text should revert to background colour when not applicable (therefore not visible) or overwrite opposite condition (running/stopped).

Status text (running, stopped etc)	White
Analogue values (e.g. flows, levels)	White
Engineering units	White
Alarms	Red
Faults	Yellow

508.3 CURVES

Curves represent and display on a colour graphic console the changes of one or several analog, digital or logic information from the storage database.

Both real-time and historical trends shall be available for all analogue values (including summated and derived) by all the following methods.

a) As an integral part of a mimic diagram.

b) As a sub-mimic-accessed from one or more 'Poke Points' on process mimics.

c) As a separate function of the SCADA package with user friendly configuration.

In any of the above methods up to four (4) values shall be available for display on the same graph simultaneously with user defined time and unit scales.

Each variable shall be presented as a graph against time, the normal period being the last 24 hours or such other time scale as is most suitable for the particular parameter, with the facility for the operator to be able to input a start time and end time. Axes shall be clearly labelled, tagged (variable name/identification) and scaled.

Each variable within a graph shall have a separate colour, either green, brown, magenta or blue.

An information can be displayed simultaneously over different time periods allowing thus the comparison of the evolution of a phenomenon in time.

Following are the main options of the curves module:

- a curve view configuration (references and display periods acquisition)
- call and loading of a curve view
- succession of curves views (following and previous view)
- query of values on a curve (selection with the mouse of the following, previous or any point)
- zoom (horizontal and vertical)
- grid display (to facilitate hardcopies reading)
- screen print on a graphic printer.

This functionality allows the comparison of a real-time variable with a previous evolution (e.g. comparison of a reservoir actual curve with that of the previous day).

The data retrieval utilities of the storage database allow the user to compare stored data with those of the on line available database.

Moreover, counter values shall be displayed in the form of histograms representing automatically the index differences over a one hour, a one day or a one month period. So, when activating the zoom, the system recalculates automatically the index differences over the zoomed in period.

Example:

- Consumption curve for a certain year: the system displays 12 bars representing each a monthly consumption.

- Zooming in on a certain month: the system displays 31 bars representing each a daily consumption.

- Zooming in on a certain day: the system displays 24 bars representing each an hourly consumption.

508.4 POKE POINTS

These are any area on the screen which, when selected by cursor, cause display or control actions to occur and shall, where appropriate, follow the guidance in BS EN 60073 for push buttons.
There shall be poke points to enable movement between process mimics both upstream and downstream without use of intermediate menus or mimics. The 'active' areas shall be sized for ease of use with a cursor and shall be represented as a symbol, icon, text or function box.

Poke points shall also be utilised for trends, menus, overviews and control activation (where applicable).

All control activation or changes of operational parameters shall require a `confirm before execute' routine.

508.5 OPERATING PARAMETERS AND SAMPLE RATES

These values shall be presented in a tabular form for each process area or sub-group.

It shall be possible to change analogue sample rates as an operator function (eg. 5 secs, 30 secs, 1 min, 30 min, etc).

508.6 LAYOUT AND STRUCTURE

The mimic displays of the overall process areas and RTU's, shall be configured based on the process and instrumentation as specified and approved.

Symbols shall be used to represent items of plant in a manner which is easily recognisable by the operator. The overview mimic shall use symbols, not just labelled blocks.

Wherever possible, flow and process direction shall be from left to right, top to bottom. The crossing of flowlines shall be avoided, however if this is unavoidable, the vertical line shall be shown with a break. Junctions of flowlines shall be only single T junctions with no local increase in line size at the joint.

In general, flowlines and symbols shall not be outlined. The colour shall be used in block or fill form, with graphical detail where necessary in white lines.

Plant status for running/stopped, open/close, available/unavailable etc... shall be indicated (on the process mimics) by text in addition to symbol colour.

Text associated with symbols shall be 3.5mm height. Text associated with headings shall be 5mm height. All text shall be in upper case.

Abbreviations of engineering shall be in accordance with SI nomenclature as detailed in BS 5555 or as otherwise approved by the Engineer. Where a percentage figure is given as data, this meaning shall be either percentage of full capacity or percentage open, e.g. 100% indicates a full tank or a fully open valve.

508.7 MENU HIERARCHY

On start up, the system shall automatically display the log on/off menu which shall be in the form of a graphical list offering the choice of access levels as follows:

1. Operator
2. Supervisor
3. System Engineer/Diagnostic Routines

Access to facilities from each level shall be changeable at the system engineer level.

Once logged on, the system shall display the main menu, offering the choice between the mimics/data pages.

'Help' screens shall be available for each mimic. These shall be user configurable by a combination of text and graphs via the SCADA package facilities.

Screen Burn: To minimise VDU screen burn, a changeable time out shall be used to either display a blank screen or remove all screen displays until any key reactivates the last screen display.

Legend: A mimic shall be provided to explain all symbols, icons, colours and functions of the system.

508.8 MIMICS (VDU)

A VDU mimic is a dynamic graphic view drawn and configured by the user. A mimic includes a number of animated objects in terms of the evolution of a set of logic, analog and digital channels.

Creation and animation of mimics shall be through a graphic tool which creates and manages a user interface based on graphic images and libraries of objects.

This graphic software has two main functions:

An EDIT function

Such a function creates images used as a dialog support with the computer system, and then sets up a link between the application variables and the image's elements. The latter being a dynamic representation of the first.

Following are the available graphic primitives:

– rectangle, circle, ellipse, text, polyline, polygon, curves.

The graphic functions are:

– bar-graphs (rectangular or circular)
– scales (linear or circular)
– discrete function (8 representations according to Boolean conditions)
– digital displays
– animated text
– mimics modifications
– objects designation (remote commands, remote setpoints).

ANIMATION function

This function ensures the display of graphic images and their animation on the basis of the data transmitted periodically by the system.

It allows also the management of input/output utilities tools provided for the user, namely : the mouse and an alphanumeric keyboard.

By using the mouse (designation, data acquisition) the supervisor can send messages which shall generate remote commands or setpoints.

Consequently, the grahic animation tool behaves like a real control board of the Center.

508.8.1 Mimic Design and Approval

The mimic design shall progress in parallel with the Functional Design Specification and Process and Instrument Diagrams. It is envisaged that at least three reviews will be required before final approval. Any changes required from these reviews shall be carried out by the Contractor and deemed to be included in this Contract.

All displays shall be submitted for approval either in floppy disk format (IBM PC (DOS based) compatible) or as a VHS video tape presentation. Whichever format is selected, it shall depict simulated changes of analogue and digital plant status. In addition colour hard copies of every page shall be submitted of an equal quality and content to that of the printer being supplied.

508.9 ALARMS

Special care is given to the management of alarms in order to facilitate and optimize interventions in case of major alarms. The system keeps an updated list of active alarms.

An alarm is present or missing, acknowledged or not acknowledged. An alarm is active in any of the following configurations:

- present and not acknowledged
- present and acknowledged
- missing and not acknowledged.

An alarm disappears in the following three cases:

- alarm missing but acknowledged
- oldest alarm on the saturated list when a new alarm appears
- alarm disappearing before the end of the delay.

In the second case an alarm message is initiated and edited on the continuous printing peripherals. An unacknowledged alarm which appears several times occupies one space only on the list, but the number of appearances is counted.

Upon initiation, alarm messages shall be displayed on the VDU and an audible alarm sounded. The visual alarm indication shall utilise colour and flashing effects to differentiate from normal information. When alarms are accepted by the operator, the audible alarm shall be silenced. Upon clearance of the alarm the VDU display shall revert to normal.

In addition to alarms listed in the instrument index, alarms derived from process evolved conditions shall be treated, displayed, logged, etc., in a similar manner to a direct alarm. The derived alarm is intended to indicate problems occurring within the process/control system and/or site equipment not covered by direct alarms. The Contractor shall ensure all problem conditions within the above parameters are included. Additional derived alarms shall be available for user definition.

Derived alarms shall signal when:

a) any item of equipment fails to respond to an initiating signal,

b) any item of equipment stops (or starts) other than when it has been instructed to,

c) any item of equipment fails to respond to a set point within an adjustable time limit,

d) any analogue signal becomes below 4 mA or above 20 mA,

e) when there is a disparity between two measureands, i.e. analogue and digital level monitoring.

The hierarchical level of an alarm determines the necessary action to be undertaken. There are eight alarm levels:

level 0 : no acknowledgment requested
level 1 : local acknowledgment requested
level 2 : acknowledgment requested, late duty staff call (if configured). Delay of call is authorized.
level 3 : alarm delay of 15 mn. In case of further delay, an acknowledgment is requested and a call is generated (if configured). If the alarm origin disappears before 15 mn, the alarm disappears from the list. Delay of call is authorized.
level 4 : idem level 3, with a 60 min delay
level 5 : idem level 3, with a 4 hours delay
level 6 : acknowledgment is requested, generation of call (if configured). Delay of call is not considered: Immediate duty staff call.

level 7 : reserved.

The alarm list may be displayed on the screen and printed upon request in whole or in part after selection of alarms in terms of their state.

508.10 ALARM LOGGING

The alarm printer shall log all alarm events as they occur, stating the following for each:

i) Alarm flagged
ii) Process area
iii) Description of alarm
iv) Tag number (if any)
v) Time alarm initiated
vi) Time alarm accepted
vii) Time alarm cleared

NB. `Engineer on Site' shall be treated as an alarm.

508.11 EVENT LOGGING

Continuous printing of events is either systematic or configured. Systematically printed events, are those related to the stations status:

– reversion to normal status after a voluntary operation or a communication failure
– detection of a communication failure after expiry of the maximum configured response time delay
– acknowledgment of the communication failure
– reversion to normal status without acknowledgment of the communication failure.

Printed events, should the associated variable be so configured, are:

– change-of-state, with alarm indication, if any
– alarms acknowledgment
– disappearance of unacknowledged alarms
– transmission of remote commands, setpoints and values
– non execution of remote commands within the set time limits
– transmission of remote commands (remote setpoints, counter index setting) which execution is monitored
– non execution of above-mentioned remote commands within the set time limits
– overstepping of a measurement threshold
– out-of-range measurements
– sensors faults
– local modifications of setpoints
– local modifications of counters
– counters reset
– updating the alarm list.

All printed messages are time-logged.

In the event of a failure in the continuous printing peripheral, the events to be printed are temporarily stored. They shall be printed as soon as the peripheral is back into operation or after they are switched over by the operator towards another peripheral.

Following is the message format:

- date of event
- label of the station
- number and type of channel
- label of channel
- description of event.

508.12 MANAGEMENT REPORTS

In order to configure reports and logs of accumulated data over a certain period, data shall be capable of being exported from the hard disk onto separate storage devices.

The reports shall be user redefinable and take the form of charts, data tables and graphs, both on demand and periodically configured.

Preconfigured reports shall be supplied as part of this Contract. Hard copies shall be submitted for comment/change/approval by the Contractor as part of the functional design specification procedure.

Reports are elaborated either by means of a spreadsheet or a graphic spreadsheet.

Spreadsheet

The system includes an automated reports compiler. Simple tables can be easily drawn up for the normal use of the system.

Tables are constituted periodically using analogue or digital values from the storage database.

There are several types of reports : EVERY SIX HOURS, DAILY, WEEKLY, BI-MONTHLY, MONTHLY, and YEARLY ...

A report is identified by its name, type, and date.

A report can include the following data:

- For an analog value (measurement)
  - value at origin of time
  - mean hourly value
  - minimum hourly value
  - maximum hourly value
  - number of invalid samples.

- For a digital value
  - index value at origin of time
  - number of invalid samples.

Graphic spreadsheet

The graphic spreadsheet is a:

- 3D graphic tool
- sophisticated display tool
- development tool with compatible language.

Macro commands are created to retrieve simply the information of the storage database, namely:

- For analog values:
  - instantaneous value at a given date/hour
  - mini, maxi, or mean value between two dates
  - mini, maxi, or mean hourly value
  - mini, maxi, or mean daily value
  - number of samples between two dates.

- For a digital value:
  - index value for a given date/hour
  - index difference between two dates
  - index hourly difference
  - index daily difference
  - number of samples between two dates.

- For a logic variable:
  - number of change of states or hourly operation time
  - number of change of states or daily operation time
  - number of change of states or operation time between two dates.

Moreover, the graphic spreadsheet allows an easy insertion of graphs in reports and tables (2D or 3D curves, bar graphs, pie charts, ...).

508.13 MAINTENANCE ASSISTANCE

The Center holds two data lists used as maintenance assistance:

- the list of operation time of machines and equipment
- the list of machines and equipment requiring maintenance and which operation time has reached an alarm value.

508.14 MENUS AND LOGS

A log of values holds several logic, analog, or digital channels under a given name : for example, the “FLOW” log, gathers all flow measurements. When the log is displayed or printed, it shows the instantaneous values of all channels included therein at the time of consultation.

A faults log is an extract of a states and values log which contains only the values of defective channels.

A values menu is a set of logic, analog or digital channels displayed according to a determined pop up dialog box. The menu is identified by a name. Upon consultation, the menu displays all values and states and shows their real-time evolution.

The menu is a dynamic alpha-numeric mimic, it is created and configured by the system’s administrator.

509. FUNCTIONAL DESIGN SPECIFICATION

509.1 PURPOSE

The Functional Design Specification (FDS) shall be prepared by the Contractor and agreed jointly by the Contractor and the Engineer. It shall detail the manner in which the Contractor intends to provide a system to meet the Engineer's/user's needs as set out in this Specification. Once agreed by the Contractor and the Engineer it shall form part of the contractual documentation.

The FDS shall describe what the system will do, how it will be operated and maintained, and what facilities and services will be provided. It shall provide a list of design objectives and forms the baseline document for the functions and extent of the proposed system.

Besides covering all system functions, the FDS shall define the reliability, maintainability, acceptability, ease of training and operation, security and overall quality policy of the proposed system.

Any divergence between the FDS and this Specification shall be resolved, agreed and clearly documented, and the FDS amended to reflect the new understanding.

When the FDS has been approved and signed by the Engineer it shall be kept under formal change control by the Contractor to cover any subsequent amendments. Change control should also be applied to any dependent documents (see Section 7 of the "Guidelines for the Documentation of Software for Real Time and Interactive Systems" published by the Institution of Electrical Engineer (IEE) London).

509.2 STRUCTURE

The following structure is suggested for the Functional Specification:

System Overview - providing an overall plan of the Contractors proposed solution. This shall take the form of a functional block diagram accompanied by a descriptive text.

System Functions and Facilities - describing all the functions and facilities proposed to meet the system objectives as specified in this Specification.

System Interfaces - specifying all inputs and outputs of the system, including communication links.

System Attributes - specifying matters relating to the adaptability, availability, maintainability and usability of the system.

Design, Development and Test Factors - specifying aspects of software, design, development procedures and system acceptance testing.

509.3 DOCUMENTATION

The above document structure shall incorporate descriptions of operation for the following conditions:

Normal operation

Back-up operation
Modes of system failures
Modes of instrument failures
Watchdog functions
Modes of power failure
Return to normal conditions
Schedules of software adjustable operating parameters

All relative supporting documentation shall be included in the functional design specification before approval and should include the following:

Process and Instrumentation diagrams.
VDU mimics
Instrument panel layouts
Access levels
Control system and loop diagrams
Software packages documentation (SCADA, etc...).
Management Reports
Instrument Index

509.4 POST-INSTALLATION DOCUMENT

Documentation shall include, but not limited to, the following:

As-built drawings.

Test, commissioning and calibration reports.

Acceptance certificates.

Standards documentation.

Drawings.

Warranty-conditions, start dates, end dates.

Hardware maintenance agreements contracts.

Fault reporting procedures.

Post-installation special-to-project software upgrade and enhancement procedures, including documentation updates.

Notification procedure and maintenance contracts for supported software updates (e.g operating system, language compilers).

Transfer of title ownership of software modules.

Permits/certificates authorising the use of licensed or leased software.

510. COMMUNICATIONS

510.1 CONTROL AND COMMUNICATIONS

The control system shall communicate with plant via one or more Remote Terminal Units (RTU). The RTU's shall be linked by a common communications link so designed that failure of any RTU connected to it or failure of the computer system shall not cause the link or data highway to malfunction.

The configuration, communications speed and number of data highways shall be determined considering the response times, distribution and number of signals presented by the Plant requirements.

The communications network for the SCADA system shall accommodate both continuous real time and timed polling acquisition of data throughout the system. The RTU's/Outstations may be polled on a pre-determined rate but shall have a real time responses to alarms.

The means of communication shall be in accordance with the Particular Specification and the following clauses relevant to the selected medium.

510.2 TRANSMISSION MODES

The telemetry system is to transmit in the Time Division Multiplex mode (TDM) with Frequency Shift Keying (FSK) or Differential Phase Shift Keying (DPSK) modulation and shall employ an interrogation/response or an indeterministic (random acquisition) system.

Suitable modems shall be provided to match the system characteristics which shall have a transmission rate to meet the system performance requirements.

The system is to detect at least 98% of all and 100% of 1, 2 and 3 bit transmission errors.

The equipment shall be suitable for the future installation of UHF radio links as an alternative to transmission over public or dedicated private lines.

510.3 PRIVATE LINES/DEDICATED LINES

Where communications between sites is to be over 2 wire private circuits rented from the local communications authority or laid along the pipeline, by the Contractor, they shall be speechband circuits (2 wire, half duplex).

Where communication links between sites are specified to comprise two independent circuits, each circuit shall use separate routes where possible. Automatic changeover to the standby line shall occur in the event of duty line failure on the links between the specified sites. The standby lines shall be continually monitored and an alarm raised in the event of failure. Adequate provisions shall be made to allow testing, debugging and servicing a faulty cable while the alternate one is in use. The data cables shall conform to ISO/IEC DIS 11801.

It shall be the Contractor's responsibility to negotiate and agree on behalf of the Purchaser with the local communications authority for the supply of all lines which must be suitable for the proper operation of the system. Any connection charges arising shall be submitted for payment by the Purchaser.

510.4 RADIO LINKS

Where it is envisaged that communication between outlying locations and the works will be by radio, the Contractor shall be responsible for carrying out a site radio survey to confirm that this method is suitable.

The results and conclusions of the survey shall be collated into a report which shall contain all documents including correspondence, calculations, etc with any statutory bodies, landowners, etc.

It shall be the Contractor's responsibility to obtain licences from the relevant licensing authority to operate the required frequencies on behalf of the Purchaser.

The Contractor shall minimise the number of frequencies he intends to use and shall justify the use of all proposed frequencies.

The Contractor shall restrict the data transmission rates over the radio links to the minimum number required for the effective operation of the system. Calculations shall be provided justifying the signalling rates.

510.5 LOW POWER RADIO

Transmission between individual or small groups of instruments to local stations for monitoring purposes should be considered wherever hardwiring would be more costly. However, control functions should be hardwired or via approved PLC units and not performed within the radio station units.

The above individual or small groups of instruments should form 'cells' within the 'cells' transmitting to a master station via a radio data network.
All systems using low powered radio must be approved to the appropriate local communications authority and shall be installed in a manner which ensures operation within the allowable frequency and power restrictions.

Antenna shall be appropriately sized, orientated and safely installed. All systems shall be of a robust nature with a full consideration given to location, access and vandal interference.

Where radio networks are proposed, available network systems shall be used which optimise the available bandwidth in each channel. The network architecture shall utilise a well established protocol designed for the radio environment operating in real time and able to guarantee data security. In addition the network shall utilise an open architecture to allow for inclusion of a wide variety of devices either existing or in the future.

It may be necessary for more than one radio channel to be utilised to guarantee performance and response. Multiple channels may be used in a cell structure providing this can be demonstrated to be a well proven network facility and does not require custom software design.

510.6 FIBRE OPTIC LINKS

All fibre-optic networks are to be bidirectional, ie. the cable shall be such that if communication through the fibre should fail at a point along the network, polling shall then reverse, maintaining uninterrupted control.

511. COMPUTER ROOMS

511.1 GENERAL

Rooms accommodating SCADA computer equipment shall be designed, decorated and furnished in accordance with the following requirements, unless otherwise detailed in the Particular Specifications.

- i) Lighting and decoration suitable for VDU viewing
- ii) Air conditioning and ventilation
- iii) Fire detection and alarm extinguishing equipment
- iv) Electrical power outlet
- v) Dust control mat
- vi) Blinds
- vii) Furniture

All items of equipment (control and electrical) as detailed in this specification shall be suitably housed and located taking into account ease of operation, noise, visitors, storage, possible future requirements, communications and external interference from adjoining rooms. Cables shall be concealed as far as possible.

All equipment and design shall be in accordance with the relative CIBSE Guides and Codes.

511.2 LIGHTING

Room lighting shall be by means of low brightness luminaires incorporating high frequency, flicker free, electronic ballasts to meet the following requirements and generally in accordance with CIBSE Lighting Guide LG3.

Average illumination (Eavg at the working surface)	-	450 Lux minimum
Emin/Eavg	-	0.8 minimum
Control	-	100%-20% or less , continuously adjustable by 1 wall mounted control knob.
Colour Rendering	-	Colour No. 84 (4000° K)
Emergency lighting	-	Minimum 2.5 hours, by self contained module attached to luminaire.

511.3 AIR CONDITIONING

Heating, ventilation and cooling systems shall be provided to meet the following requirements.

Maintained Temperature	21°C $\pm$2°
Maintained Humidity	50% RH $\pm$10%

Heat Dissipation in room	To be calculated by the Contractor based on 2 persons and installed equipment occupancy
Number of Air Changes	4 changes per hour minimum

The systems shall be of the heat pump type, able to provide sufficient heating when required, either of one piece or split design.

The Contractor shall determine all fabric loads.

The installation shall include materials and labour for connection of the equipment to a suitable electricity and water supply within the building.

The method of drainage for the equipment shall be in accordance with the regulations as laid down by the local authority.

The systems shall be inter-connected with the fire detection equipment such that the air conditioning equipment shall be shut off with the ventilator firmly closed in the event of fire being detected within the room.

511.4 FIRE DETECTION AND EXTINGUISHING EQUIPMENT

Fire detection and warning equipment shall be provided in accordance with BS 5893 to include the following items:

Optical smoke detector
Break glass fire alarm switch
Single zone microprocessor controlled fire alarm panel compatible with the equipment herein specified, with battery back-up and failure monitoring.
Pulsed tone alarm mounted inside control room.
Audible alarm suitable for external use and audible for a distance of at least 200m to be mounted on the building exterior.

The components shall be mounted in a position to be agreed with the Engineer.

The system shall be supplied with suitable contacts to shutdown the air conditioning system and provide an alarm contact to the SCADA system. In addition, 2 spare contacts shall be supplied.

Fire extinguishing equipment shall be supplied and mounted in agreement with the local Fire Officer.

511.5 ELECTRICAL POWER OUTLETS

Where additional socket outlets are specified, they shall be switched socket outlets to match the local standards.

The outlets shall be installed approximately 20cm above floor level. Installation shall include for wiring back to the building distribution panel, additional components therein and connection thereto as required.

Where outlets are supplied from the UPS, traffolyte engraved labels approximately 25mm x 50mm shall be supplied and mounted above each such socket, with the following wording, white on red background.

FOR COMPUTER EQUIPMENT ONLY

511.6 DUST CONTROL MAT

A dust control mat, having anti-static properties shall be supplied of approximately 1m x 1.5m, dark grey carpet with bevelled non-trip edging to be placed in front of the doorway to trap foot borne dust and dirt.

511.7 BLINDS

All windows shall be fitted with fully adjustable vertical louvre window blinds which shall be light grey in colour.

511.8 FURNITURE

Purpose made computer tables, sized to accommodate the specified printers, VDU's, storage drawers and working space shall be provided, together with any other chairs, cupboards etc, as detailed in the Particular Specifications. All items shall be supplied with the following considerations:

a) Anti-static material
b) PC units mounting below desk top
c) Storage of paper consumable and transportable mediums
d) Storage of system disks and manuals
e) Paper trays (fan paper)
f) Working area
g) Phone locations
h) Cables hidden.

511.9 DECORATION

The walls and ceiling shall be painted in semi-matt emulsion of pastel shades to be agreed with the Engineer.

Prior to painting, the surfaces shall be well prepared (and primed) in accordance with the manufacturer's recommended painting system for the material.

PART 6

TESTING AND COMMISSIONING OF MECHANICAL AND ELECTRICAL EQUIPMENT

TABLE OF CONTENTS

601. GENERAL REQUIREMENTS

“In factory tests” shall be carried out if requested in the Particular Specifications.

“Commissioning tests” (tests on completion) shall be carried out at the end of the works following pre-commissioning.

“Performance tests” shall take place during the defects liability period. Test shall be consistant with the specifications of the contract document and the standards in force.

Analytical instruments for testing shall be sealed and supplied with recent calibration certificates provided by an official laboratory.

The results of tests shall be set out in a report signed by the Engineer or his representative and by the Contractor.

601.1 ABBREVIATIONS

The following abbreviations are used in these documents :

1/head/day	liters per head per day
AC	Asbestos Cement
AGMA	American Gear Manufacturer’s Association
AOD	Above ordnance datum
BS	British Standard
CDR	Council for Development and Reconstruction.
CFM	cubic feet per minute
Ch	Chainage
CMR	Continuos Maximum Rating
CP	Code of Practice
CPU	Central Processing Unit
DI	Ductile Iron
DIN	Deutsch Industrie Normen
DOV	Double Orifice Valve
DPSK	Differential Phase Shift Keying
DTU	Documents Techniques Unifiés
EDL	Electricity of Lebanon
EMC	Electromagnetic Compatibility
EOH	End of hole.
FDS	Functional Design Specification
FIDIC	Federation Internationale des Ingénieurs- Conseils
FSK	Frequency Shift Keying
g	acceleration due to gravity ($9.807 m/s^2$)
GL	Ground level
gpm	gallons per minute
gr	gram
GRP	Glass Reinforced Plastic
GTSD	General Technical Specification Document
hr	hour
I/O	Input / Output
IEE	Institute of Electrical Engineer

ISO	International Standards Organization
ITS	Institute of Technical Studies
kgf	kilogram force
kPa	kilo Pascal
kVA	kilovolt-ampere
kW	kilowatts
kWh	kilowatt hour
LED	Light Emanating Diode
m	meters
m/s^2	meters per second per second
m^3	cubic meters
m^3/day	cubic meters per day
MDPE	Medium Density Polyethylene
mgd	million gallons per day
mhd	meters head
mm	millimeters
NFE	Normes Françaises - (Electrical)
NLQ	Near Letter Quality
NPSH	Net Positive Suction Head
PS	Particular Specification
PTT	Poste de Téléphone et de Télégraphe
PVC	Polyvinyl Chloride
PWL	Pumping Water Level
RAM	Random Access Memory
RBC	Rotating Biological Contractor
RTR	Reinforced Thermoplastic Resin
RTU	Remote Terminal Unit
SCADA	System Control And Data Acquisition
SOV	Single Orifice Valve
SPTD	Signal Pole Double Throw
SSU	System Supervisory Unit
SWL	Static Water Level
TDH	Total Dynamic Head
TDM	Time Division Multiplex
TEFC	Totally Enclosed Fan Cooled
UHF	Ultra High Frequency
UPS	Uninterrupted Power Supply
UPVE	Unsaturated Polyvinyl Chloride
VDU	Video Display Unit
VGA	Video Graphics Array
VHF	Very High Frequency
VHS	Video Home System

602. IN FACTORY TESTS OF PUMPSETS

602.1 GENERAL

Pump testings shall be determined according to the pump tests carried out by an international control organisation, i.e. EUROPUMP, the committee of European manufacturers of pumps which divide them into two classes :

- Class A : special pumps
- Class B : small pumps manufactured in large quantities.

Class A

The Engineer or his representative shall determine, in the description of the project, whether the pump(s) or its (their) motor(s) shall be tested in factory.

The Contractor shall submit the original estimate of the manufacturer, justifying the costs of the required in factory tests. The price shall be detailed according to the requirements of the Engineer.

Class B

Equipment manufactured in large quantities shall not undergo in-factory tests.

The manufacturer shall produce, for the manufacture criteria and their justifications, the characteristic curves of each pump ordered by the Contractor :

- Flow curve
- Efficiency curve
- Power curve
- Suction curve (NPSH)

The complete control of operation conditions shall be carried out as soon as the equipment is installed on site.

Where pumps operate in series or in parallel, the Contractor shall justify the operation characteristics by producing analogous curves specifying the starting and releasing points for an automatic or manual operation.

602.2 PUMPSET TESTS

Verifications and tests shall be carried out in factory, in conformity with the international tests standards in force in the country of origin or with those equivalent to international standards adopted for the manufacture of the equipment before transporting the equipment.

These tests shall be carried out at the expense of the Contractor, and under the supervision of an international control organisation, i.e. EUROPUMP.

The international control organisation shall be considered as “The In-Factory Taking Over Agent”. Nevertheless, in factory taking over shall not supersede the on-site “Taking Over Of Works”.

These tests shall allow a complete control of all the guarantees stipulated in the tender document, as well as the verification of the equipment consistency with the adopted manufacture standards. They shall also provide the information mentioned hereinafter.

In particular, these tests shall be carried out at the maximum nominal speed and in conformity with the adopted standards.
However, no tolerances shall be permissible in any way regarding the guarantees of flows, lift heights, and efficiency.

Tests shall include, particularly :

For the pump :

- The determination of the lift head of water at the specified flow rate set out in the tender document.
- The determination of the flow at the TDH.
- The drawing of characteristic curves (efficiency, NPSH, required power, “head - flow” curve).
- The determination of the pump efficiency at the specified flow.
- The determination of the pressure when the discharge outlet is closed while pump is running.
- The hydrostatic test.
- The determination of the inertia of revolving parts.

For the electric motor

- The determination of the nominal power.
- The determination of the nominal speed at the nominal power.
- The determination of the nominal current under working voltage.
- The determination of the starting current in case of direct starting.
- The determination of output shaft torques (nominal, starting, breakdown) and the drawing of the characteristic “torque-speed” curve.
- The determination of the efficiency at the duty point.
- The determination of the efficiency at 2/4, 3/4, and 4/4 of the load.
- The determination of power factors at 2/4, 3/4 and 4/4 of the load.
- The determination of the inertia of revolving parts.
- Heating tests
- Dielectric tests

– Overspeed tests

– Measurement of the noise level.

Prior to the installation of equipment, the Contractor shall submit to the Engineer in triplicate the tests and “in factory taking over” certificates, duly certified by the International Control Organisation, attesting that the tests carried out on the equipment meet the conditions of the Contract and that the equipment is in conformity with the specifications of the tender document.

602.3 “IN FACTORY TESTS” PENALTIES

Unless otherwise specified, if the values of efficiencies and flow rates recorded during the “Factory Test” are not in conformity with the declared values, penalties shall be calculated as follows:

– Declared Overall Efficiency = (Declared Efficiency$_{Mtr}$ X Declared Efficiency$_{Pump}$) at the TDH.
– Declared Fow Rate = Flow rate at the TDH.

- 2% of the value of the equipment for each 1% of overall efficiency inferior to the declared values.
- 1% of the price of the equipment for each 1% flow rate inferior to the declared flow rate.
- 0.5% for each 1% flow rate superior to the declared flow rate.

The maximum total penalties on efficiency and flow rates shall be fixed at 5% of the motopumpset value, beyond this rate the motopumpset shall be rejected.

When the power required by the pump is not compatible with the motor provided, the motopumpset shall also be rejected.

603. TESTING ELECTRICAL PANELS IN WORKSHOPS

Tests of each electrical panel must include at least the following verifications :

- Verification of the aspect, accessibility of mechanical equipment, as well as strength and operation of mobile elements, precautions taken to prevent corrosion and protect paint, wires and cable runs, and marking operations, etc...
- Verification of the good functioning of mechanical and electrical control devices as well as efficiency of locking mechanisms.
- Verification of the electrical insulation.
- Verification of the continuation of sheathings.
- Verification of Earthing connections.

Moreover, all electrical equipment constituting the panels should have undergone in-factory tests determined by the relevant standards: IEC 439, etc...

604. TESTING OF VALVES

All valves shall be tested in accordance with BS pressure and material test certificates shall be submitted to the Engineer for approval.

605. ON SITE TESTS

They are carried out on electromechanical plant, generating sets and control systems.

Tests shall comprise, but shall not be limited to, the following:

605.1 VISUAL INSPECTION

- Checking the state of the equipment and the quality of work.
- Checking levels and alignments.
- Verifying the effective characteristics of the equipment.

605.2 ACOUSTIC TESTING (NFS 31-010 AND BS 7445-3)

Regulations related to the noise caused by machinery, in order to protect the neighborhood and the environment, are stipulated by the legislation governing installations classified as noisy.

The surrounding noise level measured from outside the building must not exceed :

45 dB (A) during day time, throughout the week
40 dB (A) from 8:00 PM till 10:00 PM throughout the week and on Sundays
35 dB from 10:00 PM till 6:00 AM during the night

The noise level may be increased according to the surrounding and to the satisfaction of the Engineer or the Employer (increase in dB (A)).

- Suburban residential area with low road traffic + 5 dB (A).
- Urban residential area + 10 dB (A).
- Urban residential area with workshops and heavy road traffic + 15 dB (A).
- Commercial or industrial area + 20 dB (A).

The tests and controls shall be carried out in some particular cases, upon an explicit request stated in the description of the tender document.

605.3 TESTING OF ROTATING ELECTRIC EQUIPMENT

605.3.1 General

All rotating electric equipment shall undergo preliminary works before their operation such as:

- Verification of the inside of the machine: rotor, stator, and magnetic core gaps of windings, presence of foreign bodies, etc... Dust removing by vacuum or compressed air (maximal pressure 4 bars).
- Verification of the correct tightening of all bolts, nuts, screws.

- Verification of all electrical protection equipment and instrumentation connections.
- Performance of operation tests and verification of the protective devices.
- Verification of electric connections and rotation direction.
- Measurement of insulating resistance and determination of the dielectric absorption ratio as directed hereinafter.
- Elimination of any condensation or humidity on the winding or the terminal box, by heating or according to the instructions mentioned below.

Upon completion of these operations, the rotating electric equipment is ready for operation.

605.3.2 Measurement of Insulation Resistance

Before measuring the insulation resistance, separate all winding terminals of each phase.

Windings of phases : (U_1 - U_2 , V_1 -V_2 , W_1 - W_2)

- With windings (V_1 -V_2) and (W_1 - W_2) connected to the frame, measure the insulation resistance between the winding (U_1 - U_2) and the frame.

- With windings (U_1 - U_2) and (W_1 - W_2) connected to the frame, measure the insulation resistance between the winding (V_1 - V_2) and the frame.

- With windings (U_1 - U_2) and (V_1 - V_2) connected to the frame, measure the insulation resistance between the winding (W_1 - W_2) and the frame.

- Measurements shall be carried out as follows : every 10 seconds, during the first minute, then every minute for the following nine minutes. It is advisable to use a motorised Megger.

- Voltage measurement values are the following :

  250 volts dc for $U_N \leq 500$ V
  2500 volts dc for $U_N > 4500$ V

- Static electricity shall be discharged with care before and after each measurement.

- The following formula shall be applied :

$$Ri \geq K \frac{U_N}{D}$$

Ri : (M Ω)	:	insulation resistance
K	:	temperature adjustment factor
U_N (KV)	:	Operation voltage of the machine
D (m)	:	Stator diameter Value = 1 if D ≤ 1 meter Value = D if D > 1 meter

The value of the factor K in terms of the temperature is given in the following table :

Winding temperature (°C)	K
20	45
35	16
45	8
55	4
75	1

605.3.3 Determination of the Dielectric Absorption Ratio

The ratio is determined by the insulation resistance measurements corresponding to the first minute (R_1) and the tenth minute (R_{10}), as follows :

$$a = \frac{R10}{R_1} \text{ with } a \geq 2$$

Where a < 2, windings shall be cleaned and dried.

605.3.4 Cleaning of Windings

– If foreign bodies deposits are located in nooks inaccessible to dusters, it is advisable to use dry compressed air (max. 4 bars)

– Vacuum cleaning is required to prevent deposits from filling holes, setting between loose windings or damaging insulators when using compressed air.

– A solvent shall be used where oil or grease is mixed with dust. The solvent shall derive from petroleum and be selected so as not to damage insulators. Upon completion of the cleaning operation windings should be completely dry.

– Water may be used to clean dirty motors due to mud or eventual floods. This operation requires the disassembling of the motor in order to clean correctly and dry out all the parts.

605.3.5 Drying Windings with Air Circulation

Uncap the winding. Install a hot air blower (electrical resistance fitted with a fan) opposite the winding. The temperature of the air close to the winding shall not exceed 70°C.

Drying shall only require few hours, depending on the relative humidity and the power of the electrical blower.

605.4 TESTING OF HANDLING EQUIPMENT

All lifting equipment shall be tested at the manufacturer's works and on site. Tests on site shall comprise a full load test, including, where applicable, deflection checks on beams. Where the contractor wishes to use lifting equipment forming part of the permanent works for installation purposes he shall have the equipment tested and be in possession of a valid test certificate before using the equipment. All equipment must be tested or retested within one month of handing over to the Employer. Test certificates shall be provided in triplicate. The contractor shall be responsible at his own cost for the provision of all weights, slings and other equipment required for testing.

605.5 TESTING OF PLUMBING & SANITARY SYSTEM

The whole of the plumbing and sanitary system is to be tested on completion to the satisfaction of the Engineer and any defects shall be made good at the Contractor's expense.
The contractor shall provide all the labour, instrumentation, materials, temporary blank-off fittings, tools, plant and equipment required to complete all tests and commissioning.
Pressure tests shall be completed before any pipes are cleaned and before any insulation or protective covering is applied.
When a section of pipe work is complete and ready for testing, it shall be plugged and then slowly and carefully charged with water, allowing air to escape and avoiding all shock or water hammer. The contractor shall make arrangements for all water used in tests to be properly drained away.
Pipe work which fails under test, due to pressure loss or visible leakage, shall be relieved of pressure and all fault joints or other defects rectified to the complete satisfaction of the Engineer.
The Engineer or his representative will witness every test and the Contractor shall liaise with the Engineer, regarding the timing of the tests. All tests shall be repeated, if necessary, until such time as the engineer is satisfied. Test certificates shall be completed by the Contractor following each test and shall be submitted to the Engineer. The certificates shall state the following:

1. Pass / Failure
2. Pipe work section / Service tested
3. Equipment / Items on section excluded from test.
4. Test pressure and duration
5. Witness signature

Following testing, all pipe work and tanks shall be thoroughly flushed out and cleaned with potable water, to the entire satisfaction of the Engineer. After cleaning has been completed, the domestic hot and cold water lines shall be sterilised as follows:

1. All hot and cold water lines shall be thoroughly sterilised with a solution containing 20 parts per million of available chlorine in the form of liquid chlorine, sodium hypochlorite or chlorinated lime.

2. The sterilising solution shall be introduced into the lines in an approved manner and shall be kept in the pipe work for 24 hours, during which time all valves shall be opened and closed several times.

3. After sterilisation, the solution shall be flushed from the lines with potable water until the residual chlorine content is not greater than 0.2 parts per million, or as directed by the Engineer.

605.6 TESTING OF HVAC SYSTEM

605.6.1 Test procedures

Proposed test procedures for duct leak and performance tests of systems, shall be submitted to the Engineer at least 4 weeks prior to the start of related testing.

605.6.2 Test on completion

Prior to taking over, the Contractor shall conduct the following tests :

605.6.2.1 Testing, adjusting and balancing

Testing, adjusting, and balancing shall be as specified in ASHRAE and/or BRITISH STANDARD related to ADJUSTING AND BALANCING OF HVAC SYSTEMS. Testing and adjusting of ventilation systems shall begin only when the entire work has been completed, with the exception of performance tests.

605.6.2.2 Temperature test

Temperature tests during 10 hours minimum, all doors and windows being closed, the premises dry, and the outdoor temperature between 28°C and 34°C in summer and between -2° C and + 6° C in winter. Inside temperature shall be measured at 1.5 meter above ground level. Supply and return air temperatures in air-conditioned premises shall also be measured.

605.6.2.3 Sound test

Sound level tests measured at 1.5 m from supply and extract gills by means of a variable frequency sound pressure level. Sound level shall not exceed 40 dBA.

605.6.3 Performance test

After testing and adjusting has been completed as specified, each system shall be tested as a whole to see that all items perform as integral parts of the system.
Correction and adjustments shall be made as necessary to produce the conditions indicated or specified. Capacity tests and general operating tests shall be conducted by an experienced engineer. Tests shall be carried out 4 weeks after all HVAC equipment has been put into operation successfully. Afterwards and after agreement with the engineer, the peak performance test shall be carried out at the time of peak outside conditions.
The equipment shall give the specified capacities at the peak conditions otherwise the equipment shall not be taken over.

605.6.4 Test reports

Test reports for the ductwork leak test and performance tests shall be submitted in booklet form, upon completion of testing. Reports shall document phases of tests performed including initial test summary, repairs/adjustments made, and final test results.

605.7 TESTING OF CHLORINATING SYSTEM

Prior to system start up all chlorination systems shall be pressure tested for leaks.

- The system shall be tested with nitrogen or dry air at a test pressure 50% higher than the service pressure. Soapy water shall be applied to all joints and connections to facilitates detection of leaks.
- The system shall be tested with chlorine. A rag soaked in liquid ammonia shall be brought to the vicinity of all potential leak points, leaks being evidenced by production of white ammonium chloride fumes. In the event of a leak, prior to effecting repairs, gas bottles shall be isolated and the lines drained through the dosing pumps.

IMPORTANT Procedure for Pressure Tests

1. Open all valves one turn except gas bottle valves.
2. Open gas bottle valves to achieve a system pressure of 1-2 kgf/cm^2 and close them again.
3. Search for leaks with an ammonia soaked rag.
4. In the event of a leak drain the lines with the dosing pumps and repair the leak.
5. Open gas bottle valves to achieve maximum system pressure.
6. Repeat 4 and 5 above.
7. When system is leak free open gas bottle valves one turn.

605.8 TESTING OF ELECTRIC, HYDRAULIC, CONTROL & TELEMETRY SYSTEMS

All tests shall be carried out according to BS 5772.

605.8.1 Testing of Electric Systems

- Time delay measurements of the units
- Insulation measurements of the various circuits
- Measurement of Resistance of Earthing bars
- Measurement of Voltage drops
- Measurement of Intensities conveyed through cables
- Measurement of Power consumption
- Correction of phases
- Measurement of Starting voltages, currents, etc...
- Measurement of Efficiency of Motors
- etc...

605.8.2 Testing of Hydraulic systems

- Surge protection
- Measurement of Pressure (upstream/downstream)
- Measurement of Flow
- Measurement of Efficiency of Motopumpsets
- Water analysis
- Valves
- etc...

605.8.3 Testing of Control & telemetry systems

- Communication links
- Safety
- Automatic operation, software
- Signals
- etc...

606. SETTING UP AND PRE-COMMISSIONING

Upon completion of works, and as soon as the equipment is ready to operate, the Contractor shall notify in writing the Engineer. The effective completion of the equipment assembling shall then be controlled in the presence of the Engineer and the Contractor by making the inventory of the equipment components. The good operation of all materials, especially of safety devices shall be checked.

The Contractor shall then set up the equipment.

During this period of "setting up", the Contractor can, upon the approval of the Engineer, stop or put in operation the equipment in order to make the necessary adjustments and be sure of their good operation.

When the Contractor deems that the equipment is ready to undergo the pre-commissioning operation, it shall be run for a period of time during which the equipment is operated according to a schedule set by the Engineer with the joint approval of the Contractor.

This period shall last fifteen days minimum, including, compulsorily, two days of continuous operation under the normal working conditions, as well as a number of successful consecutive startings to be agreed on with the Engineer.

During this period, equipment should operate without giving rise to any manufacture or setting up defect, that would lead compulsorily to putting them out of service. The Contractor can proceed to setting up operations during normal stop hours whenever he deems it necessary.

If, during this period, operating equipment give place to any incident, and, should the Contractor be bound to stop the equipment, outside normal stop hours, for any modification, setting up or adjustment, the period shall be extended to a duration equal to that of the interruptions.

In the same way, if the equipment should be stopped during the two days of continuous operation, the contractual period of 2 day continuous operation is counted all over again from the next starting.

Where frequent interruptions or the continuation of operation may cause any danger, the Engineer has the right to interrupt the operation, after having notified the Contractor. In this case, the Engineer gives the Contractor a delay reduced as much as possible and in accordance with the operation possibilities of the moment, to modify the equipment so that it conforms to the specifications of the Contract. After setting up defective parts, the equipment is put into service and the Contract during of the pre-commissioning period is counted all over again from that moment.

During setting up and operation periods, defined here above, the Contractor shall be responsible for the equipment. He shall overhaul, repair or carry out necessary modifications at his own costs.

607. TRAINING THE EMPLOYER PERSONNEL

During the period of assembling and especially during the period of pre-commissioning operation, the Contractor shall train the personnel assigned by the Employer. The training shall be carried out at 3 principal levels:

a) Engineers
b) Control and maintenance technicians (assistant engineers)
c) Skilled workers

The instruction of levels b) and c) shall be carried out with the collaboration of level a) already trained.

The training program, as well as the number of persons participating in the training shall be established by mutual agreement with the Employer, and upon his approval.

During the period of pre-commissioning, the Contractor shall hand over to the Employer's personnel the respective operating and maintenance manuals of the equipment.

608. COMMISSIONING

At the end of the satisfactory pre-commissioning operation, and if the Contractor has started training the Employer's personnel, the commissioning of the equipment shall start. It shall be deemed started and a report shall be drawn thereof provided that the Contractor has submitted to the Engineer a written request, along with a copy of the drawings, notices and documents necessary to the operation and maintenance of the equipment.

Starting from the commissioning operation, the Employer's personnel takes over the operation and the maintenance of the equipment under the supervision of a sufficient number of qualified technicians assigned by the Contractor.

These technicians shall supervise the personnel till the end of the commissioning.

The commissioning period is fixed to a minimum continuous duration of twenty eight days, during which the equipment shall function satisfactorily and require only minor secondary setting up or adjustment entailing no stops and revealing no systematic defect.

In case any setting up, adjustment or defect entails the stopping of the equipment during the commissioning period, the minimum period of twenty-eight days mentioned above should compulsorily restart as from the resumption of the normal commissioning operation.

During the commissioning period set above, the Contractor's supervising technicians shall continue training the personnel assigned by the Employer.

Until the taking over, and provided the operation requirements permit it, the Contractor shall carry out, at his own costs, all necessary replacements, modifications, setting up and adjustments.

609. TAKING OVER OF WORKS

After the end of the commissioning period and upon a written request submitted by the Contractor, it shall be proceeded, in the presence of the Engineer and the Contractor, to the taking over provided that the equipment has functioned without requiring more than minor setting up or adjustments and without showing any systematic defect or default occurring during the minimum continuous period of twenty-eight days, and not in conformity with the technical specifications set in the tender document.

Taking over should include an inventory of the equipment and the tests set in the technical specifications, in order to verify whether the equipment meet, in quantity and quality, the conditions of the Contract.

The date and the schedule of the Taking Over are fixed by mutual agreement between the Engineer and the Contractor.

The Contractor shall carry out all necessary works and installations, and supply and assemble the equipment used for tests.

The Contractor is bound to inform the Engineer of all the defects he has detected.

In case operation incidents occur before taking over, the Engineer shall reserve the right to ask for an exhaustive inspection of the main components (pumps, motors, etc...).

The taking over shall be the subject of reports mentioning the necessary repairs and setting up.

The tests carried out eventually by the Contractor during the periods of setting up and commissioning shall not be taken into consideration and shall be carried out once again during execution of the official tests on completion.

In case part of the equipment is rejected under any condition set hereafter in section “Rejection Of Equipment”, the taking over of equipment, which is not rejected and is in accordance with the taking over conditions, is declared, provided that the equipment can be used independently from the rejected part.

Taking over takes place after achievement of satisfactory tests on completion.

the taking over shall be the subject of a report signed by the two parties.

It is agreed that, in case taking over is not declared, equipment remain under the responsibility of the Contractor.

Consequently, the Contractor shall bear along the consequences of all incidents or accidents occurring to the equipment before the signature of the taking over certificate.

The equipment shall, in no case, be considered as commissioned de facto.

610. DEFECTS LIABILITY PERIOD

The Contractor guarantees that all the supplies delivered according to the terms of the Contract are new, have never been used, are of the latest pattern put into service and have undergone all necessary improvements relating to design and materials.

Moreover, the Contractor guarantees that all the delivered supplies have no defects owing to their design, to the constituent material or to their use.

The Defects Liability Period remains valid for 12 months as from the date of Taking Over.

During the Defects Liability Period the Contractor shall supervise the maintenance of the installations.

During the Defects Liability Period, the Contractor is bound to carry out all modifications, setting up, adjustments required for the replacement of the defective parts, so that the equipment meet the conditions set out in the Contract.

If during the Defects Liability Period an equipment is stopped due to defects attributable to the Contractor, especially in the case of abnormal wear, deterioration or misfunction of a main component, the Defects Liability Period for this equipment is extended to cover the period of time during which the equipment was out of order.

If during the Defects Liability Period, it is necessary to replace a component due to an abnormal wear, deterioration or misfunction, the Defects Liability Period of this component is counted from the moment the replacing parts are put into service. In this case, the Engineer can, at the end of the Defects Liability Period retain an amount of money equal to twice the price of the component determined at the moment of the replacement. This amount shall not be fully paid up until the end of the Defects Liability Period proper to this component, provided that the latter was proved consistent with the clauses of the Contract.

The Contractor affords all the expenses resulting from the above-mentioned operations including the cost of transportation, on site disassembling and reassembling and customs dues, etc...

Are excluded, expenses resulting from a deterioration owing to a negligence or an operation error and attributable to the Employer, or due to operation conditions that are not consistent with the instructions of operation and maintenance given by the Contractor. After having examined these defects not attributable to him, the Contractor shall inform the Engineer within a period of ten working days only, under a penalty of foreclosure.

The Contractor is not responsible for the components supplied, repaired, modified or replaced by the Employer or his representative without the written approval of the Contractor. However, this does not include the cases where the Employer carries out urgent repairs or replacements in the event of non compliance by the Contractor to the conditions mentioned hereinafter.

If it has been proved that the noticed defect is caused by a systematic error of design of equipment, the Contractor should replace or modify all identical parts used on the other equipment mentioned in the Contract, even though they did not give rise to any accident.

All works incumbent on the Contractor during the Defects Liability Period should be executed as soon as possible, taking into consideration the operation requirements.

The Contractor should, however, afford all provisional repairs to meet to the best these requirements, while reducing to the minimum the time during which equipment is partially or totally not operational.

The end of the Defects Liability Period will be declared following satisfactory Test On Completion results.

611. MAINTENANCE SUPERVISION DURING THE DEFECTS LIABILITY PERIOD

From the provisional taking over and till the end of the Defects Liability Period of all supplies, the Contractor shall ensure :

– the supervision of the maintenance of the installations carried out by competent technician

– the supervision of the necessary check-ups. The Employer shall bear the cost of workmanship, except those of the contractor’s technicians.

– the supply of necessary spare parts. Therefore, the Contractor shall store on site all spare parts required for operation during the Defects Liability Period.

– the follow up and the further training of the Employer’s personnel, as regards the operation and maintenance of the installations.

612. REJECTION OF EQUIPMENT

The Engineer reserves the right to reject the equipment under any of the following conditions:

a) If during the period of installation and assembling, several componentsof the any equipment are discovered to be defective.

b) If the Tests On Completion show deviations with regard to the required flow and efficiency values specified in the Particular Specifications at the TDH.

c) If, during the Defects Liability Period serious defects occur (not allowing a safe operation and unlikely to be repaired by the Contractor within reasonable delays).

The Engineer can only reject the entire equipment if it shows serious defects which make its use dangerous or very expensive.

In the other cases, only the parts (of an entire machine) not answering the conditions of the Contract are rejected.

Before declaring the rejection, the Engineer shall examine, according to the elements submitted by the Contractor, the possibilities of :

a) either limiting the rejection to the seriously defective parts.
b) or fixing a delay to overhaul the equipment so that it meets the conditions of the Contract.

The Engineer may allow replacing the rejected equipment at the expense of the Contractor, during this time, he can:

– either renounce using the rejected equipment,

– or, use the equipment under the responsibility of the Contractor and upon his approval, on condition that several modifications, adjunctions or eventual adjustments are carried out, at the expense of the Contractor, either by him or by a supplier, if any. Therefore, the Engineer can, gratuitously, use the rejected equipment, and undertake to use it under the normal operation and maintenance conditions.

In all the cases mentioned above, rejected parts are returned to the Contractor.

613. OPERATION AND MAINTENANCE MANUALS

The Contractor shall supply for each set of installations provided for in the Contract, bilingual Operation and maintenance manuals (Arabic, French or English).

They shall include a table of contents and complete relevant material to the following sections as a minimum:

- Warnings
- General description
- Pumps control and protection
- Pumping station start up procedure and run operation
- Settings
- Preventive maintenance
- Trouble-shooting procedure
- Bill of material
- Drawings
- Manufacturer catalogues.

Unless otherwise specified, the instructions and the documents thereto shall be supplied in 3 copies properly presented and protected.

PART 7 - BOREHOLES

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701 FIELD OF APPLICATION AND SCOPE OF WORKS

The present Tender Document shall apply to waterwells drilling works. The works shall include the following:

1. Drilling of the wells by percussion or rotary method:
   - Determine the hydrodynamic characteristics of the aquifer.
   - Determine the physical and chemical quality of the pumped water.
2. Geophysical logging for work diagnosis in order to:
   - Locate permeable and production zones.
   - Locate impermeable zones.
   - Evaluate the clay content of the aquifer.
   - Evaluate water mineralization.
   - Measure the depth of the well.
   - Measure the static level in the well.
3. Installation of temporary casing.
4. Grouting works.
5. Installation of the final casing and screen column.
6. Well development works.
7. Well development control.
8. Pumping test works.
9. Control the plumbness and alignment.

702 SPECIFICATIONS OF MATERIAL AND EQUIPMENT

The present Tender Document determines the technical specifications of the materials and the construction products to be used.

702.1 GENERAL SPECIFICATIONS

The materials and equipment, as well as their eventual coating should not change the physical, chemical or organoleptic qualities of water in the water well.

Moreover, they should ensure a maximum guarantee against corrosion.

702.2 CASINGS AND COUPLINGS

702.2.1 Casings

a) General

The casing string is used to prevent the collapse of the waterwell walls and protect, along with grouting, the underground water or the aquifer from being contaminated by the underground or surface pollutants. It also protects the pump.

The pipes shall have sufficient resistance to withstand the pressure exerted by the walls of the waterwell, or that exerted on the column during installation, as well as the corrosion caused by the soil and by water in some cases.

Pipe lengths shall be such as to draw up ground water to the surface through tender layers and contaminated zones.

In porous water-bearing aquifers, the casing string depth should exceed the proposed depth of the well by at least 1.5 m and be preslotted in sandy and gravelly formations.

In hard formations, the casing string should exceed the proposed depth of the well by 2.5 meters and be grouted.

Special care should be taken while installing the casing string and the screen column.

Steel is generally the most frequently used material. Less common materials may be required namely, stainless steel, copper alloys, nickel, silicon, bronze, aluminum and non-ferrous metals, so as to meet very special conditions imposed by the nature of water or the ground. All materials should be compatible when used in the construction of boreholes. No process of corrosion, deposition or other chemical reaction should result directly or indirectly from the juxtaposition of dissimilar materials. Special care shall be exerted when handling these materials given their high cost and the low resistance of some of them.

The tubes shall be content with the specifications of:

THE AMERICAN SOCIETY FOR TESTING MATERIALS (ASTM)
THE AMERICAN PETROLEUM INSTITUTE (API)
THE AMERICAN WATER WORKS ASSOCIATION (AWWA).

It should be noted that these specifications are for horizontally and not vertically placed pipes. Moreover, the most widely used pipes are made of stainless steel, while some casings are manufactured from metal sheets that are welded lengthwise or helicoidally.

b) Diameters of final casing

The diameter of the casing string shall be two inches larger than the diameter of the mounted pump. Under no circumstances shall the diameter of the casing be one inch larger than that of the pump.

The dimensions of the casing have been determined based on the dimensions of the vertical turbine pumps with speeds up to 1800 rpm. Taken into consideration are also head losses created by the water movement between the screens and the pump.

Table 1 shows the minimum diameter of casing in relation to the pump size and the discharge rate. Moreover, it should be noted that the minimum acceptable diameter of the casing should be 8 inches (203 mm), to allow for repairs.

Table 1: **Minimum diameter of casing in relation to the pump size and the discharge rate:**

Nominal Diameter of pump (inches)	Rotation velocity of pump (rpm)	Discharge rate (L/sec)	Minimum diameter of casing (10 mm)
	1800	< 6.3	150
	1800	4.7 - 11	200
8”	3500	12.6 - 76	250
	1800	6.3 - 38	
	1200	10 - 25	
10”	1800	12.6 - 95	300
	1200	23 - 42	
12”	1800	25 - 145	350
	1200	16 - 95	
14”	1800	63 - 284	400
	1200	50 - 220	
16”	1800	126 - 328	450
	1200	82 - 215	
18”	1800	202 - 340	500
	1200	139 - 252	
	900	177 - 190	
20”	1200	195 - 347	600
	900	145 - 227	
22”	1200	473	600
	900	227	

For submersible pumps, the minimum diameter of the casing mentioned above should be increased by 2 inches.

c) Thickness of the final casing

The casing string in water wells shall be made of steel, the thickness of which allows to withstand tensile strength, compression and crushing.

The thickness of the casings shall be determined according to their diameters and the depth along which they are installed (Table 2).

Table 2: **Thickness in (mm) of the casing versus depth**

DIAMETER inches DEPTH m / DEPTH m	6	8	10	12	14	16	18	20	22	24	26
0-30	2.78	2.78	2.78	3.57	3.57	4.36	4.36	4.36	4.36	4.36	4.76
30-60	2.78	2.78	3.57	4.36	4.36	4.36	4.76	4.76	4.76	4.76	6.35
60-90	3.57	3.57	4.36	4.36	4.36	4.76	4.76	4.76	6.35	6.35	6.35
90-120	3.57	4.36	4.36	4.76	4.76	4.76	4.76	6.35	6.35	6.35	7.9
120-180	3.57	4.36	4.76	4.76	4.76	6.35	6.35	6.35	7.9	7.9	7.9
180-240	4.76	4.76	4.76	4.76	6.35	6.35	6.35	7.9	7.9	9.5	9.5
> 240	4.76	4.76	4.76	6.35	6.35	6.35	6.35	7.9	9.5	9.5	11.1

d) Type and thickness of temporary casing

In the event that the Contractor should use, while carrying out the works, temporary casings, their technical specifications will be set by the Engineer according to the lithology of the layers encountered, the depth of the well and the diameter of the bits etc...

The use of temporary casings requires the approval of the Engineer. Generally, these casings are made of black steel welded lengthwise with a minimum thickness of 5mm.

702.2.2 Couplings

Under no circumstances should two pipes of similar diameter be connected by an internal coupling. The Contractor shall make sure that the couplings and the body of the pipes are equally resistant to breakage.

702.3 SCREENS - TYPE AND SPECIFICATIONS

702.3.1 General

Screen columns comprise the following:

- A screen (continuous or discontinuous when separated by one or several non perforated casings).
- A gravel pack.

In unconsilidated aquifers and under certain conditions in consolidated aquifers, screens should be placed opposite the production zones to allow free flow of water into the well, and to prevent the entry of aquifer material having a good uniformity coefficient, but which do not clog the screen openings.

For a non homogenous and porous aquifer having a uniformity coefficient less than 3, and an effective grain size of 0.254 mm, screens fitted with gravel packs shall be used. In this case, if the non homogenous aquifer is less than 1.5 m thick and separated vertically by impervious strata of less than 1.5 metres thick, the gravel pack shall be used provided that the screens are more than 1.5 metres long, and regardless of the uniformity coefficient of the aquifer.

In certain cases, gravel packs are used to stabilize aquifers having a high percentage of fines. This prevents the setting of layers over the screens. In aquifers with fissured rocks, screens shall catch the production zones and retain the walls of the waterwells.

703.3.2 Type

To reduce the corrosion damage, screens and their threading should be made of the same type of materials; the selection of which will mainly depend on the chemical quality of the water. Nevertheless, it is recommended that the material type used for the screens is that of the non perforated casing or very close to it on the galvanic scale.

Screens are preferably made of stainless steel (18.8 active) or semi-stainless steel. It is possible to use screens made of reinforced plastic upon the approval of the manufacturer and with regard to the required mechanical conditions.

Other types of materials may also be used such as ordinary steel, or galvanized steel coated with RILSAL or other anti-corrosion products.

Unless otherwise stated, the Contractor will abide by the pipes standards set by API, 5 L grade B; lengthwise welded, with electrical resistance or induction welding without using filler metal.

702.3.3 Screen aperture sizes and diameters

There are various forms of apertures: circular holes, slots and bridge slots. Their main characteristic is the net open area (5% to 50%) according to the grain size analysis of the aquifer. Based on to the granulometric curve of the aquifer plotted during previous tests, screens must retain 90% of a relatively heterogeneous formation and 70% of a relatively homogenous one.

Screen openings and diameters are selected for each water well according to the water inflow (a velocity equal to or less than 1.8 m/minute or 3 cm/sec), the grain size analysis of the aquifer formation and the lithological nature of the aquifer.

702.3.4 Screen length

Screen lengths are selected according to the following criteria:

a) Homogenous and artesian aquifers:

- If the thickness is less than 7.5 m, it is necessary to screen 70% of the aquifer.
- If the thickness varies between 7.5 m to 15 m, it is necessary to screen 75% of the aquifer.
- If the thickness is more than 15 m, it is necessary to screen 80% of the aquifer.

b) Non homogenous and artesian aquifer. It is necessary to identify the most permeable zones through:
- Permeability tests in laboratories if the samples were representative.
- Grain size analyses.
- Geophysical logging.
- Photographic logging.

It is to be noted that these tests and analyses except for the logs, are not required under the present Tender Document. They are mentioned here for indication purposes only. The Engineer will determine with the Contractor the levels that must be screened.

c) Unconfined and homogenous aquifer: the screen should be positioned in the lower third of the aquifer.

d) Non homogenous and confined aquifer (dense stratification): the length of the screen shall be equal to one third of the aquifer thickness.

Note: The screen is generally installed opposite the most permeable and deepest level.

702.3.5 Screen type selection

The types of the required screens are the following:

a) Aquifer with fissured rocks:
- Bridge slot screens.
- Louvred screens.

b) Porous aquifers
- Slot wire wrap screens.
- Artificial silica filter screens (precast) the characteristics of which shall be in accordance with the grain size analysis of the aquifers. (The particular specifications of these gravel packs are given in the Article 702.4.1).

702.3.6 U.P.V.C. casings and screens

Thermoplastic casing

They shall be non-toxic, non-corrodible, non-taint and internationally approved for potable water use, and shall contain an ultra-violet inhibitor. The Contractor should specify the thermoplastic type intended for usage.

This casing string shall be new and must be constructed in accordance with the relevant ASTM Standards. Their ends shall be threaded in accordance with the API 5A/5B Standard for short round threads or equivalent.

Thermoplastic screens

They shall be of the same material as any thermoplastic casing offered for approval and shall comply in all respects with the casing specifications.

Slot widths

They shall be 0.5 mm and slots shall be perpendicular to the long axis of the screens. The open area of the screens shall not be less than 6%.

It is the responsibility of the Contractor to provide the rate of the screens in m^3/hr and the relevant curves.

a) Length of the casings and screens

Casing and screens should be provided as follows:

- 20% of all casing and screen materials shall be provided in nominal 3 m lengths.
- 80% of all casing and screen materials shall be provided in nominal 6 m lengths.

The Contractor shall also provide a catalogue comprising the technical specifications of the casings and screens and all other necessary technical details:

- Collapse resistance.
- Permeability of the screen with respect to slot sizes.
- Diameter of casings with respect to compressive strength.
- Thread specification and the threading method.

b) Physical specifications of the materials

- Density 1.4 g/cm^3 (DIN) 53479).
- Elasticity models: 2500 - 300 N/mm^2 (DIN 53457).
- Tensile strength: 44-55 N/mm^2.
- Shock resistance at 20 °C: rupture at 10% maximum according to DIN 53453.
- Thrust resistance at 20 °C: 3-5 KJ/m^2 according to DIN 53453.

c) Chemical specifications of the materials

- U.P.V.C. material shall be resistant to:
- all ground waters.
- sea and brackish waters.
- acidic solutions.
- alkaline solutions.
- and in general, all chemical substances used during drilling operations, rehabilitation and disinfection of wells.

Table 3: Characteristics of U.P.V.C. casings and screens:

a) U.P.V.C. casings and screens for wells with depths up to 300 m.

Diameter (inches)	Diameter (mm)	Minimum thickness (mm)	Resistance to buckling (Bar)
8	200	13	18
10	250	16	18
12	300	19	18
14	350	21.5	18

b) U.P.V.C. casings and screens for wells with depths up to 500 m.

Diameter (inches)	Diameter (mm)	Minimum thickness (mm)	Resistance to buckling (Bar)
8	200	16.7	43
10	250	18.5	29
12	300	21.5	27
14	350	24	27

702.4 GRAVEL PACKS

Two types of gravel packs are required in the present Tender Document.

(a) The gravel pack with siliceous grains attached to the screens and directly poured during the installation of screens.

(b) The ordinary gravel pack placed in the water well after the installation of the screen column (non perforated casings + screens).

702.4.1 Precast gravel pack attached to the screens

The precast gravel pack consist of siliceous grains.

In the first case, the siliceous gravel shall be characterized by:

- a sphericity coefficient: 0.6
- a uniformity coefficient varying between 1.4 and 2.5
- a total percentage of silica: 98.8
- an open area > 10%
- an entrance velocity: 3 cm/sec.

The granulation of this type of pack is mentioned in the addendum. It is defined according to the flowrate, the hydrostatic pressure and the grain size. The grains of the filter material shall be glued and shall adhere to the external metallic surface of the screen by means of a plastic polymer product characterized by a high chemical resistance.

Nevertheless, in certain water wells this gravel pack shall be externally protected by punched screens (and not bridge slotted screens) made of the same metal used for the internal screen and non-perforated casings. In all cases pipes shall be consistent with the standard set by API, 5L grade B.

702.4.2 Ordinary gravel pack

The gravel pack shall consist of well rounded, clean and uniform grains. They must be made of silica and calcareous materials not exceeding 5% in weight. The density should not be less than 2.5 with a tolerance up to 1% in weight for a density equal to or less than 2.25.

The gravel must not contain, in weight, more than 2% of fine, flat and elongated particles visually observed. It shall not contain clay, mica, sand, dust, organic impurities as well as sufficient quantities of iron or manganese capable of altering the quality of water.

Gravel shall be supplied and transported to the site in bags weighing 25 to 50 kg.

The quantity of gravel to be placed in the wells is mentioned in the bill of quantities.

Crushed, calcareous, and dolomitic granulates used as a filter material are excluded.

702.5 WELL GROUTING

702.5.1 Sand cement grout

A mixture of PORTLAND cement (ASTM - C150), sand and water, in the proportion of not more than 2 parts by weight of sand to one part of cement, with not more than 26 liters of water per bag of cement (0,028 m^3 or 28 liters or 42.6 kg) shall be used. The use of bentonite to reduce permeability of the cement during pumping must be approved by the Engineer.

702.5.2 Cement grout

If the mixture consists only of cement and water, the dosage shall be 40 to 50 liters for every 100 kg of cement PORTLAND ASTM C 150. Seventy-five liters of cement grout having a density of 1.9 shall be obtained.

In order to facilitate the calculations of water and cement quantities used to obtain a certain volume of cement grout the Contractor can use the chart on figure 1.

The use of bentonite to reduce the risk of permeability during pumping is conditional upon using 70 to 75 of water, 3 to 5 kg of bentonite per 100 kg of cement and this only upon the approval of Engineer.

703 SITE ORGANIZATION

703.1 WORKS INSTALLATION

The location of water wells to be drilled is indicated on the drawing mentioned in the addendum. The exact location of works will be determined on site by the Engineer who has the right to modify certain locations, when necessary, without giving the Contractor the right to claim for indemnity. The Contractor must visit the locations and evaluate the constraints before submitting the proposal.

703.2 SITE INSTALLATION

Most wells have an easy access but may require some preliminary works such as:

- Demolition of artificial obstacles (fences, old buildings, etc...)
- Grading of lands and access roads.
- Stripping of lands.
- Installation of channels to deviate the water course and avoid flooding some houses or buildings during pumping tests and well development.

The soil must have a maximum slope of 4% and a sufficient consistency enabling a normal installation of drilling equipment.

The Contractor shall also protect all the existing buildings, vegetation, pipes etc... During works execution and until their completion, the Contractor shall remove excess spoil earth and unused materials... and reinstate the soil or the site before handing it over. He will get rid of packings used for fluids or flamable products as well as no longer needed materials. The Contractor shall restore at his own expense buildings and fences etc... if they have been demolished during works, upon the request of the Engineer.

703.3 WELL PROTECTION

The Contractor shall at all times take measures to prevent contamination of the wells from any surface water, petrol, oil or other polluting material or substance. He shall maintain the site in a sanitary condition at all times and shall fill in pits and clear upon completion, and remove from the surface of the ground all rubbish, surplus spoil, and litter which have been left on site.

The Contractor shall be responsible for the disposal of drilling fluids, water expelled during well development, and pumping test discharge and shall do so in a manner that does not cause contamination or nuisance.

703.4 MATERIAL AND EQUIPMENT

The Contractor shall submit for approval a detailed and complete list of the equipment and materials he intends to use on the site for the execution of works.

Apart from the equipment particular to borers, the site must include auxiliary trucks, cistern trucks, ordinary vehicles, a set of spare parts, electrical generator, electrical and oxyacetylene welding units, a set of tools and other various equipment necessary for such works.

704 EXECUTION OF WORKS

704.1 DRILLING, DEEPENING AND REAMING OF BOREHOLES

704.1.1 Drilling and deepening

Drilling is accomplished either by the rotary or percussion method. Since wells will penetrate layers characterized by important various facies (lithologic nature), the Contractor shall be free to choose the most appropriate drilling method.

Nevertheless, the Contractor shall abide by all the instructions given by the Engineer, as well as the technical specifications of this Tender Document to complete the works as required. If the Contractor resorts to the ROTARY method, he has the right to use mud, foam, water or air to ensure that well cuttings are continuously taken. However, the Contractor will inform the Engineer about the fluids he intends to use at each stage of drilling and the appropriate dosage of components. The Contractor shall only use these fluids (mud, foam, etc...) upon the approval of the Engineer.

In the event of total or partial loss of circulation, the Contractor shall take all necessary measures to limit such losses, and inform the Engineer who will decide whether to continue the works under these conditions.

If the Contractor uses drilling mud to consolidate the walls of the well, he must wash the well with water after the casing is installed, to remove all the mud and obtain clear water. He must then, upon the request of the Engineer and according to his instructions, clean the well with polyphosphates and wash it thoroughly with water of approved origin. The Contractor should also have at his disposal all the pumps necessary to well construction.

A complete and detailed list of all the equipment used in drill rigs must be produced when submitting the bid.

If the well is to be drilled by a percussion rig, which permits penetration in unconsolidated or unstable rocks, the accumulated cuttings in the well shall be removed and the well casing forced down progressively. In consolidated and hard rocks, samples are taken by bailing. The well casing is not introduced into the hole until drilling operations are completed.

The Contractor shall present a detailed schedule of the works to be carried out, taking into account the specifications of each well. He shall then submit a price for the rotary drilling and another for the percussion drilling.

704.1.2 Reaming of wells

At times, it may be required to enlarge the well diameter. Consequently, the Contractor shall submit in his proposal the reaming equipment to be used and get the prior approval of the Engineer. He should also submit a separate price list for reaming these wells to the appropriate diameters.

704.2 SAMPLES AND MEASUREMENTS

704.2.1 Samples

For each borehole, the Contractor shall take soil samples:

- At the end of each drill pipe connection for rotary drilling and every three meters for percussion drilling.
- At each change of formation.
- At each fractured formation.
- At each water flow.

Samples of 200 to 300 g shall be securely closed in plastic bags and clearly labelled with the location of the well, well number and extraction depth. These samples shall be submitted upon the request of the Engineer, and kept for 3 months.

704.2.2 Measurements during the works

During drilling operations, the Contractor shall measure:

<u>In hard formations</u>

- The top and thickness of these formations, the fractured zones and the depth of water inflows, starting from a determined and fixed reference point which is the Ground Level.

- The water level in the well at the beginning and end of the working day, at each change of bit and at each important new water inflow.

- Speed of progress at each change of formation and bit replacement.

These different measurements shall be registered in the daily report.

<u>In other formations</u>

- The depth at which a change in the lithology occurs starting from a determined and fixed reference point.

- The depth of the first encountered water level.

- The lithologic logging of every drilled formation.

- The water levels during drilling operations, at each important new water inflow, as drilling operations are completed and before equipping the well.

- The speed of progress at each change of formation and bit replacement.

704.3 GEOPHYSICAL LOGGING

Geophysical logs shall be conducted by competent personnel provided by the Contractor or by a commercial logging service so as to compare the results with the existing lithological data and to gather information about the hydrodynamic characteristics of the aquifer formation, grouting, water quality etc...

The required logs to be conducted in cased boreholes are the following:

- Water temperature log
- Water conductivity log
- Caliper logging.

The required logs to be conducted in uncased boreholes are the following:

- Spontaneous potential.
- Resistivity log (short normal, long normal, lateral).
- Natural gamma ray
- Caliper
- Fluid-movement log (measurement of upward and/or downward flows by means of a current meter).

These logs shall be conducted either by continuous recording on a roll of paper, by moving electrodes at a constant speed in the borehole or through a series of punctual measurements at each depth. If the latter method is applied, the Contractor shall execute a punctual measurement at each half meter starting from the static water level in the well according to the instructions of the Engineer.

As for the log of the vertical fluid movements in the well, it shall be carried out only in uncased wells having reached or penetrated fissured water-bearing rocks.

This log will be executed in two stages:

– First, the Contractor shall measure the vertical movement of water in the well, at the static level.
– Second, the Contractor shall take the same measurement but at the dynamic level.

Therefore, he shall install in the well a few meters below the static level, a submersible pump able to discharge a very low flowrate (less than one liter/sec) and shall wait for the drawdown water level to stabilize before taking measurements. The pumping process in the well shall last until the completion of the entire log.

The correlation of velocity measurements performed at the static and dynamic levels enables the Engineer to locate the fissured zones and evaluate their flow.

Caliper logs shall be undertaken on each well on at least two separate occasions. The first shall be on completion of reaming at the final diameter to full depth, the second on completion of casing and screen installation.

In the event of certain problems that hinder the progress of works in the well, the Engineer may ask for video recording the borehole above and below the water table.

The Contractor shall state clearly in his bid:

– The type, kind and characteristics of equipment to be used.
– The name of the company which shall execute and analyze the measurements.
– The characteristics of the submersible pump used to conduct the fluid-movement log at the dynamic level, as well as the method of supplying the pump with power.

After conducting the logs, the Contractor shall submit the final driller’s report in which the following results will be clearly stated:

- Lithologic log of the borehole.
- Location of production zones.
- Length of the grouted sections, and quality of cement.
- Chemical quality of water.

704.4 INSTALLATION OF TEMPORARY AND/OR FINAL CASING

The Contractor shall state clearly the method of casing installation taking into consideration the type of the encountered formation, the drilling method, and the screen column to be introduced into the well.

The Contractor shall see that the well is cleared out from any cavings before the casing installation. He shall also make sure that the casings are well lined up. He shall connect steel pipes either by progressive welding while making sure that the pipes are well wedged or by screwing if the pipes are threaded male and female and joined by couplings. The welding process is executed according to the standard NFE 04-021. The diameter of welding rods to be used shall be in conformity with standard ISO 864 or NFA 81-301.

If the casings are threaded and joined with coupling, they shall be connected by means of plain clamps fixed under the couplings. The technical specifications of these couplings are mentioned in the figure enclosed (Fig. 3).

Non perforated casings are placed vertically at the base of the well. If the annular space between the wall of the well and the casings exceed 0.1 m, the Contractor shall install on the pipe every 10 meters, 4 centralizers.

The deviation of the casing string, measured in comparison with the surface, shall not exceed an angle equal to 1 sexagesimal degree for every 30 meters drilled.

When the whole string is introduced into the well, it shall be suspended by a clamp laying on the soil surface, and the guiding pipe. The method of fixing the clamps and their dimensions are indicated in the figure enclosed (Fig. 2). It is noteworthy that the extremity of the lowest pipe shall be fitted with a welded or screwed plug.

704.5 REMOVAL OF EXISTING CASING

Wedged casing can be removed either by mere traction resorting to the hoisting cables of the rig or by means of appropriate jacks.

The Contractor can also apply the sand-locking or sand-joint method. He shall use a pulling pipe with a diameter approximately equal to half that of the casing or the screen to be pulled out.

On the lower end of the pulling pipe there shall be welded an inverted cone, on which is fixed a burlap sack. The whole set shall be introduced into the casing pipe (as shown in the enclosed fig. 3), while the upper edge of the sack remains on the ground. The sack then shall be filled with clean sand of medium grain size and brought down easily to the selected level.

The Contractor shall gradually lift the pulling pipe to compact the sand and create the lock between both pipes (pulling pipes and screen). Additional tension is applied to the pulling pipe by means of winches and then, if necessary, by lifting jacks.

After the pipes have been pulled out, the sack shall be removed with bailers if necessary. The table below indicates the quantities of sand to be used according to the diameters of the casings.

Table 4: **Diameter of the fishing pipe with respect to the diameters of the casing and screens as well as the quantity of sand to be used:**

Nominal diameter of casing and screen in mm	Inside diameter of casing and screen in inches	Diameter of fishing pipe in mm	Quantity of sand	
			L/m	g/f
100	3	25	3	0.23
125	4	50	6	0.42
150	4 7/8	75	7	0.52
200	6 5/8	100	13	1.0
250	8 5/8	125	24	1.9
250	8 5/8	150	18	1.4
300	10 3/8	150	34	2.7
400	13 1/8	200	51	4.0
400	13 1/8	250	29	2.3
450	15	250	57	4.5
500	17	300	66	5.2
600	21	300	144	11.4

704.6 INSTALLATION OF WELL SCREEN

Screen installed continuously shall be joined either by welding or by threading. Welding rods and methods recommended by the screen manufacturer shall be utilized. Male-female threaded screens shall have threads and couplings consistent with the standard API 5L.

Alternating screens shall be joined to the non-perforated casings either by welding or threading. Weld methods shall be in accordance with the materials used and the recommendations of the manufacturer. The Contractor shall specify the welding method and the types of rods to be used.

704.7 INSTALLATION OF GRAVEL PACK

The filter material shall be placed in the annular space by gravity through a tremie pipe. During installation of the pack, the tremie pipe is raised periodically as the filter material builds up around the well screen.

In wells where the static water level is deep (> 150 m), the gravel feed into the pipe shall be carried out with clean water stream.

The Contractor shall frequently control the depth of the filter material in the well as the work progresses.

704.8 SANITARY PROTECTION OF WELL

704.8.1 Protection of pipes, screens and filtering material

Non- perforated casings, screens and gravel packs should be cleaned from any stain and flushed with clear water before they are introduced into the well.

704.8.2 Temporary well covers

The Contractor shall install an efficient temporary cover on the wellhead during works interruption in order to prevent any pollution, damage or accident.

704.8.3 Height of the head casing

The head casing shall be at least 50 cm above the ground in order to prevent direct water infiltration.

704.8.4 Sealing of pipes and connections

All non perforated casings and connections shall be sealed, and no openings shall be allowed in order to prevent contamination in the aquifer.

704.9 WELL GROUTING

Grouting involves filling part of the space around the casing (usually between the casing and the drilled hole) with a suitable slurry of cement. The reasons for grouting are to seal the annular space, avoid the contamination of the aquifer by surface water and protect the casing, firmly anchored in the ground, against corrosive waters.

Grout may be forced into the annular space by air or water pressure, especially when it is to be placed below the static water level. Centralizers may be required to maintain a uniform thickness of cement around the casing.

704.9.1 Bailer dumping

Grout material shall be placed in a bailer and dumped in the bottom of the hole. Grout shall not be dumped more than 30 cm above the bottom of the hole, and a maximum of ten minutes shall elapse between successive dumping operations.

Curing time before resumption of drilling shall be:

- 72 hours minimum for PORTLAND cement type 1.
- 36 hours minimum for PORTLAND cement type 3.

704.9.2 Gravity filling

This method shall be used for wells having a maximum depth of 10 m.

704.9.3 Gravity filling (Tremie method)

Tremie method shall be used where there is a minimum annular space equal to 3 inches (6.62 cm) between the walls of the well and the casing.

The minimum inside diameter of the tremie pipe shall be equal to 2 inches (5.08 cm) . When making a tremie pour, the tremie pipe shall be kept full continuously from start to finish of the grouting procedure with the discharge end of the tremie pipe being continuously submerged in the grout and raised slowly as grout material is introduced.

Curing time before resumption of drilling shall be:

- 72 hours minimum for PORTLAND cement type 1.
- 36 hours minimum for PORTLAND cement type 3.

704.9.4 Positive placement (exterior method)

The annular space must be equal to 3.81 cm (1.5 inches) and the grout pipe shall have a minimum inside diameter of 1 inch (2.54 cm).

Grout shall be placed from bottom to top in one continuous operation. The grout pipe may be slowly raised as the grout is placed but its discharge end must be submerged in the unplaced grout at all times until grouting is completed.

If operations are interrupted for any reason, the pipe should be raised above the ground level and not lowered into the slurry again until all air and water in the pipe have been displaced by grout.

Curing time before resumption of drilling shall be:

- 72 hours minimum for PORTLAND cement type 1.
- 36 hours minimum for PORTLAND cement type 3.

704.9.5 Positive placement (interior method)

The grout pipe shall extend, airtight, through a sealed cap on the casing head of the well. The casing head shall be laterally equipped with a relief valve connected to the mud pump. It shall withstand the relatively high pressure that might be exerted during grouting operations especially for deep boreholes. The pipe and the annular space are then filled with fresh mud and clear water.

A spacer plug shall be inserted in the casing head. It shall be made of material that can be drilled easily such as wood, rubber or plastic, and shall have a diameter enabling it to be pushed down inside the casing. Two or three thin rubber rings slightly larger than the diameter of the pipe shall ensure an efficiently sealing plug.

The casing head shall be recapped after having verified that the plug is pushed down just beneath the lateral pipe.

Grout shall be injected into the casing by a mud pump (or a special pump), the technical specifications of which are enclosed in the Contractor’s technical offer.

After pumping all the grout into the casing, a measured volume of grout equal to the measured volume of mud shall be pumped into the casing forcing the plug to the bottom of the casing and expelling the grout into the annular space surrounding the casing until it reaches the surface.

A mud and grout seal of low viscosity shall be formed at the lower end of the casing. The spacer plug and grout seal shall be drilled out easily untill the cement has set. The water in the casing shall be held under pressure to prevent backflow of the slurry until it has hardened. Setting time is equal to 24 hours for superficial pipes and 48 hours for other pipes.

The adjunction of bentonite can increase the viscosity of grout.

704.9.6 Selective internal grouting

When only the upper part of a casing shall be grouted, a cement basket shall be attached to the casing and a 1 or 2m long plug placed in it. Above the plug, several holes are cut into the casing to allow the passage of grout.

704.10 WELL WASHING AND CLEANING

When mud is used as a drilling fluid, the well shall be washed with clear water through a direct injection at the base of the screen column. This operation shall last as long as water is muddy.

It shall include, upon the request of the Engineer treatment with polyphosphates so as to disperse the mineral mud or accelerate the biodegradation of the organic sludge (this development method is mentioned in article 704.11.3a).

In some cases, washing shall be carried out under a high pressure (50 bars) with lateral jets that unclog the screen or clear out the filtering material from any plugging deposit. In this case, the Contractor must use a pump and jet tools, the technical specifications of which are submitted for approval. It is noteworthy, however, that the distance between the injector and the screen should not be less than 10 mm.

704.11 WELL DEVELOPMENT

This operation is essential before exploiting the drinking water well, it decreases to the maximum well and aquifer losses by eliminating fine particles of sand and clay detrimental to the operation of the well pump.

Well development techniques can be dynamic (surging and pumping) or chemical (treatment by acid or polyphosphates). They can be combined in order to obtain the best results.

The Engineer shall determine for each well the most appropriate development technique, and the Contractor shall specify in his bid the cost of each method according to the bill of quantities.

704.11.1 Development by surging

This process consists of introducing into the screen column, a surge plunger operated by a percussion rig.

The movement of the surge plunger shall be controlled by predetermined reference points indicated on the cable.

The plunger shall be lowered gently but lifted briskly and quickly in order to cause a powerful depression in the aquifer forcing the water into the screen column.

The well shall be bailed or otherwise cleaned. The plunger is brought down below the stastic level of the aquifer formation, into the casing string but should at no event be inserted into the screens.

Upon completion of development, the well shall be cleaned to the bottom.

In this method of development, the Contractor shall submit to the Engineer for approval the characteristics of the surge plunger, the frequency of the upward and downward motion, as well as the method for bailing the well upon completion of surging operations.

704.11.2 Development by pumping

The process and method to be applied are as follows:

a- Interrupted overpumping

Interrupted overpumping shall include short pumping periods (2 hours) followed by idle periods (2 hours), enabling the water recovery.

The Contractor shall supply the pumping and discharge equipment required for application of this development method.

The Contractor shall bear energy cost, installation and dismantling costs of the pump, discharge pipes, and electric cables...

b. Progressive overpumping

This process consists of increasing the discharge flow to exceed the projected yield. It shall only be applied to wells in alluvial or sandy soils.

The Contractor shall bear energy cost, installations and dismantling costs of the pump, discharge pipes, and electric cables...

c. Variable pumping rates

The well shall be pumped at four successively higher pumping rates. Each step shall last sufficiently to obtain a quantity of suspended materials less than 20 mg/l. Any additional step should be approved by the Engineer. Eight to ten steps may be required to determine the maximum yield of the well.

The Contractor shall bear energy cost, installation and dismantling costs of the pump, discharge pipes, and electric cables...

704.11.3 Chemical development of wells

a. Polyphosphates treatment

Polyphosphates are used to disperse clay particles in the aquifer formation or in the gravel pack. They are tetrasodium pyrophosphate (TSPP), or sodium hexametaphosphate (SHHP) and should not be left for more than 12 hours in the well.

About 50 kgs of polyphosphates should be used for each cubic meter of water in the well. The product must be injected to water that is circulated by means of a submersible pump which draws up water and discharges it at the wellhead (closed circuit).

- This method of development shall be executed in agreement with the Engineer. In this case, the Contractor indicates the type of polyphosphates and the amount he intends to use as well as the injection depth.

- The addendum to this Tender Document indicates the technical specifications of the development pump for each well.

– The Contractor shall bear energy cost and installation and dismantling costs of the pumps, the discharge pipes, electric cables, etc....

Upon completion of the polyphosphates treatment, the Engineer shall pump the water until the well becomes clear from any phosphate traces ($PO4 \leq 1$ mg/l).

b. Acid treatment

Acid treatment is applied on development wells to reduce and/or remove any form of plugging due to incrustations. This type of treatment shall be required only when pipes are stainless steel, upon the request of the Engineer and after having taken and analyzed samples of on pumps, suction pipes and screens incrustants.

The analysis of these incrustrations allow to:

– Establish the nature and composition of incrusting materials.
– Deduce the acid nature to be selected.

for example, an appropriate acid may diminish the quantity of carbonate incrustration, but may not affect silica or aluminum silicates.

b. 1 Treatment with hydrochloric acid or muriatic acid

Hydrochloric acid dissolves rapidly the calcium carbonates.

An inhibitor is added to minimize the acid's corrosive effect on steel casings and screens; however, it has no effect on zinc which is immediately attacked by hydrochloric acid. Therefore, this acid cannot be used on galvanized steel screens.

Hydrochloric acid has a slight effect on iron and manganese incrustations, and may result in the deposition of insoluble iron and manganese hydroxides if the PH is > 3. It is recommended to use another acid if the incrustations contain large quantities of metal oxides.

Hydrochloric acid, prepared commercially under the name Muriatic acid is sold in different concentrations. The most common is 20 degrees Baume, which at a temperature of 15 °C yields 31.69% of hydrochloric acid in weight, consequently it is sold with a water content equal to 68.31%.

The solution density is greater than water density, which facilitates its utilization at the bottom of wells.

Hydrochloric acid is delivered in glass or plastic demijohns usually containing 70 kg of this solution, or in wagons or cistern-trucks coated with ebonite.

The acid shall be discharged when used by gravity or siphoning or under low pressure equal to 0,5 bar.

The inhibitor has the consistency of a gel. It is melted in very hot water. The dosage ranges between 2 and 3 kg of gelatine in 400 L of acid.

Method of Operation

Before placing acid into a well, the Contractor must carry out a test on calcium carbonates and on a sample of the metal of which the screen is made.

1) Low pressure acid treatment

A small diameter pipe of 25-35mm, made up of ordinary steel or plastic material and fitted with a T-shaped coupling shall be used. It is introduced to the bottom of the borehole, and is supported by a flange fixed on the upper end of the casing.

Acid is used upon delivery. The volume to be used is 1.5 to 2 times the internal volume of the screen. If the screen is more than two meters long, half of the solution must be injected; then the pipe should be raised to the upper end of the screen, to inject the remaining acid and fill the screen with acid.

The gas flow forces out a certain quantity of water that might contain acid.

Some form of mechanical agitation, such as surging or bailing, should be employed. The use of a bailer allows the extraction of deposits and silts resulting from the acid treatment.

Agitation time shall last for one or two hours, the deposits shall then be extracted until water becomes clear.

When using the bailer, it is immediately noticed whether the treatment has improved the flow.

It is possible to resume the operation one or several times with the same acid quantities by extending the agitation time.

2) High pressure acid treatment

When connecting the injection pipe to a special pump, the acid can be injected under a certain pressure inside the screen. All the parts of the pump in contact with acid shall be stainless steel: rods, pistons, jackets...

The pump shall have undergone a test pressure 3 or 5 times higher than the injection pressure which is equal to 150 bars for a 400 L/mm flow. The injection pipe shall be made of steel and mounted on the casing cap by means of tested threaded connections.

A pressure gauge and a safety valve shall be installed along the lift line.

The pressure should be carefully controlled during the entire operation. A pressure increase shall be noticed followed by a pressure drop indicating the beginning of the dissolving action of the acid.

It is advisable not to extend the injection operation for more than 45 minutes, since acid will no longer have an effect on incrustation and the inhibitor’s effect will decrease very rapidly with time, and its corrosive effect on steel will be minimized.

After breaking the pressure, a bailer is introduced and the solution is agitated vigorously to extract the reaction products.

Since acid treatment is somehow a delicate operation, the specialized firm shall be fitted with adequate protective equipment.

3) Precautions

Commercial grade concentrated hydrochloric acid can cause deep skin burns. The fumes released from the well are toxic and can generate headaches and nausea.

It is advisable to wear rubber gloves and goggles.

If the operation takes place in closed premises (pumping station), proper ventilation should be maintained and a breathing respirator should be used by the personnel.

By using sodium bicarbonate, the action of acid on skin or clothes can be neutralized.

It is important to make sure that no exploited wells, boreholes or springs are located within a radius of 50 to 100 meters.

Upon the completion of the acid treatment, it is recommended to considerably pump the water from the well for at least two hours until the acid is completely eliminated. This can be verified with a litmus paper.

b) Treatment with sulfamic acid

Although it is not as commonly used as hydrochloric acid, sulfamic acid offers a number of advantages.

sulfamic acid or amino-sulfamic acid, NH_2SO_3H, is especially used when descaling industrial and food contact equipment.

It is a crystallized colorless and non hygroscopic solid. Its solubility in water varies with temperature: 100 gr. of water dissolve:

- at 0 °C, approximately 15 g of crystallized sulfonic acid.
- at 15 °C, approximately 20 g.
- at 30 °C, approximately 26 g.
- at 80 °C, approximately 47 g.

Its effect on the encrusting materials in the water wells is stronger than that of the hydrochloric acid.

These salts, calcium or magnesium sulfonates are obviously more soluble in water than the salts produced by other acids.

The crystallized sulfamic acid is delivered in paper bags, lined with polyethylene containing 50 kg of dry powder product.

It is possible to store, transport and handle it without special care as long as it in crystal form.

In its dry form, it is relatively safe to handle: the dry material does not give off fumes and will not irritate dry skin. The acid should be premixed at surface before being used.

It is not necessary to transport empty or filled demijohns or containers as in the case for hydrochloric acid.

Once dissolved, the sulfonic acid is slightly corrosive. It barely effects metals such as copper or stainless steel, while it reacts chemically with ordinary steel in the same manner as hydrochloric acid although at a slower rate.

It is possible to add an inhibitor, the THIOUERA which reduces even more its little corrosive effect. However, just like hydrochloric acid, it is absolutely prohibited to use sulfamic acid on zinc or galvanized steel.

The solution shall be prepared on site in a tank and injected into the well under a high or low pressure (refer to hydrochloric acid). It is noteworthy that once dissolved the sulfonic acid reacts in the same manner as hydrochloric acid, thus requiring the same precautions: gloves, goggles, breathing apparatus, ventilation, etc...

Sulfamic acid can be poured directly into the well and is dissolved in the water. Agitation of the water with a bailer according to the prescribed dosages, and the water temperature in the well, increases the solution rate of the chemical.

The adjunction of a moistering product can improve the effect of the sulfamic acid on the incrustation. The supplier will choose a product that does not foam and is stable in acids.

c. Chlorine treatment

Acid treatment has no effect on bacteria culture and their gelatine deposits that somehow clog watercourses. The acid radically kills bacteria, but does not attack their deposits.

Chlorine kills bacteria, oxidizes and burns organic sludge. However, it is necessary to use it in high concentrations (100 to 200 p.p.m.).

It is possible to use calcium or sodium hypochlorite directly in the well or as a solution. Chlorine gas is more efficient but its use requires special equipment only available in big firms. In fact, chlorine gas is extremely corrosive, toxic and should not be inhaled.

During treatment, chlorine gas (15 to 20 kgs) is usually conducted through a small-diameter plastic tube into the well, where it mixes during 10 to 12 hours with the water.

It is not necessary to raise the pump. A centering devise should be used to keep the lower opening of the plastic pipe well centered in the well screens so that the chlorinated solution is not directly discharged on the pump, the pipe or the screen.

After the chlorine solution has been introduced in the well, it should be forced through the screen-slot openings into the water-bearing formation by adding water to the well.

A volume of water 50 to 100 times more than that of the water normally contained in the borehole shall be injected.

Calcium hypochloric contains about 70% free chlorine.

If this product is used to provide chlorine, the quantities mentioned above for chlorine gas treatment shall be divided by 0.7 so as to obtain the required weight of a lime hypochlorite.

If the pump is dismantled, it is possible, after having injected the required chlorine, to introduce a bailer and agitate the chlorine solution in the well in the same manner as in the acid treatment. If the pump remains in the well, agitation can best be achieved by pumping and backwashing (closed circuit).

704.12 PUMPING TESTS

The Contractor shall resort to a specialist hydrogeologist to carry out a series of tests, and analyse the results according to the methods particular to each type of aquifer.

The parameters to be calculated are:

- Permeability (k)
- Transmissivity (T)
- Storage coefficient (S)
- Leakage coefficient.

Pumping tests require the measurement of several parameters:

- Time
- Water depth
- Flow

Pumping tests should allow the determination of the well losses (water well test) and the calculation of the hydrodynamic characteristics of the aquifer (aquifer test) so as to establish the yield of the water well.

704.12.1 Well test

The Contractor shall carry out a pumping test at different rates (step drawdown test) in order to determine minor losses in the water well and calculate the development efficiency regarding the flow. This is considered to be very critical. Pumps shall be of the electrical submersible type capable of supplying the flows mentioned in the addenda according to corresponding depths. The Contractor shall be responsible for the supply, installation and dismantling of the pumps at the end of testing.

The step drawdown test shall consist of up to four flow higher pumping steps of discharge. Each step shall be of approximately 4 hours duration and shall be followed by a period of recovery of not less than 2 hours. The maximal flow shall consist of several flow fractions (Q; 2 Q; 3 Q; 4 Q = maximal flow). During each step, the discharge rate shall be maintained constant.

704.12.2 Aquifer test

This test shall determine the hydrodynamic parameters such as transmissivity and storage coefficient. The use of at least one piezometer - when possible - near the tested well is recommended especially for the calculation of the storage coefficient, to establish the pumping production zone in the aquifer and the protection perimeter of the water well.

However, the installation of a water level measurement device during pumping is compulsory.

The constant rate discharge test shall be of seventy-two (72) hours duration or as directed by the Engineer. The lift flow must be as close as possible to the utilization rate of the water well, or slightly less than the critical flow previously determined in the step drawdown test.

The constant rate discharge test shall be followed by a recovery stage of a duration not less than twelve (12) hours. During the recovery stage care must be taken to avoid artificial disturbance to the water level in the test well and removal of the pumping unit must await completion of the recovery stage.

In the event of interruption of a stage or step during pump testing operations, for a maximum of 30 minutes per 24 hours, the Contractor shall repeat the test at a time to be decided by the Engineer. The Contractor shall bear the cost of any test that is interrupted where in the opinion of the Engineer the interruption is due to negligence by the Contractor or to failure, breakdown or inadequacy of any of the Contractor's equipment, or where the collection or recording of data or samples is unsatisfactory.

704.12.3 Flowmeters

Flowmeters are measured either by calibrated volumetric flowmeters, or by the differential pressure method, orifice method or volumetric method. The Contractor should determine precisely and clearly in his bid the specifications of the equipment he intends to use as well as the accuracy of the measurements ($\pm$ 3%).

The static water level in each borehole shall be measured immediately before pumping. Throughout the duration of each test, the water levels and discharge rates shall be measured and recorded with the following frequency:

Elapsed time since beginning of	Minimal frequence of the flowrate measurement.
• pumping process • flow rate change	
Between 0 - 2 minutes	every 30 seconds
Between 2 - 10 minutes	every minute
Between 10 - 20 minutes	every 2 minutes
Between 20 - 60 minutes	every 5 minutes
Between 60 - 120 minutes	every 10 minutes
Between 2 - 3 hours	every 15 minutes
Between 3 - 12 hours	every 30 minutes
Between 12 - 24 hours	every hour
More than 24 hours	every 2 hours

Measurements of water levels during pumping test shall also be made on observation wells (which may comprise existing boreholes, boreholes previously drilled under this Contract and/or dug wells) not exceeding four in number and within a radius of 1 km from the pumped borehole. The frequency of measurement on such boreholes or wells within a radius of 200 m from the pumped boreholes shall be the same as that at the pumped borehole. Measurements of water levels in boreholes or wells at a distance greater than 200 m from the pumped boreholes shall be at one (1) hourly time intervals, the first measurements being immediately before and after pumping test has commenced.

704.12.4 Level measurements

Meters shall have a minimal precision in centimeters, and give a reading every 30 seconds.

The Contractor shall leave on site two meters to ensure the safety and the continuity of level measurements.

Levels shall be measured according to an easily identified mark kept unchanged. The probe used for water level measurements shall be brought down in the well inside an open and perforated pipe made of P.E. or galvanized steel, the lower part of which reaches the pump.

The Contractor shall clearly state in his bid the type of probes he intends to use and the pipes to be installed.

The Contractor shall abide by the following minimal frequency for water level measurements.

Elapsed time since beginning of the	Minimal frequency of the flowrate measurements

- pumping process
- flowrate change
- pump stop (recovery)

Between 0 - 2 minutes	every 30 seconds
Between 2 - 10 minutes	every minute
Between 10 - 20 minutes	every 2 minutes
Between 20 - 60 minutes	every 5 minutes
Between 60 - 120 minutes	every 10 minutes
Between 2 - 3 hours	every 15 minutes
Between 3 - 12 hours	every 30 minutes
Between 12 - 24 hours	every hour
More than 24 hours	every 2 hours.

704.12.5 Time measurement

It is essential to connect closely flowrates and water level measurements with external phenomena that might affect the results, for example: operation or stopping of a nearby pumping station...

Flowrates and water level measurements shall be calculated in a relative time, in minutes and seconds, with respect to the starting of the pumping process, by means of a chronometer (tenth of a second). Incidents occurring during pumping (operation and stopping of pumping, flow variations, pump breakdown) shall be written down according to the absolute time, minutes and seconds given by a watch or a clock adjusted to the local hour. The Contractor will be responsible for supplying the equipment measuring relative and absolute periods of time.

704.12.6 Evacuation of pumped water

The pumped water shall be disposed of in an area far enough from the well undergoing pumping tests or located in a slightly pervious zone in order to avoid the return of the pumped water into the aquifer, which might alter pumping test results.

The Contractor shall evacuate at his own expense the water pumped during these tests towards the point of disposal determined by the Engineer.

704.12.7 Energy

The Contractor shall provide the site with an electrical generator supplying the pump with power during the entire period.

704.13 DISINFECTION OF WELLS

704.13.1 Type and concentration of disinfecting agents

Wells shall be disinfected after pumping tests and before the pumps are dismantled.

Disinfection shall be carried out with dry chlorine or chlorine solution that is supplied and transported to the site in special containers bearing the original label indicating the percentage of free chlorine. These compounds must not be exposed to the atmosphere or to direct sunlight.

The final concentration of free chlorine in the waterwell shall be equal to 50 p.p.m. The quantities to be injected in the well where the volume of water is known, should be calculated in terms of the compound used and their percentage of free chlorine.

The Contractor shall mention in his bid the compound trademark (solid or liquid calcium, sodium hypochlorite, solid Perchloron, liquid Purec, liquid Chlorox, javel water...) as well as its percentage of free chlorine. He shall also indicate the quantities to be used in each well.

704.13.2 Disinfection procedure

The chlorine solution having the appropriate concentrations for well disinfection shall be prepared on the surface and then rapidly poured into the well to thouroghly flush the portion of the well above the static water level.

The Contractor shall then operate the submersible pump which lifts a considerable water flow up to the surface and reinjects it through the piezometric pipe (used to measure water levels) into the well.

This procedure shall last 12 hours, after which the well water is to be pumped until the concentration of residual chlorine in the waterwell is less than 0.1 mg/l. The Contractor shall select the disposal point for the purged water so as to minimize potential damage to aquatic life or vegetation.

704.14 DAILY DRILLER’S LOG REPORT

The Contractor keeps a daily report in which he shall give a technical description of the works:

- Site characteristics:
  - Date
  - Name
  - Personnel and equipment on site.

- Elements related to drilling on site:
  - Drilling methods and tools (type and diameter)
  - Speed of progress
  - Casing pipes (diameter and length)
  - Incidents during drilling operations.

- Elements related to equipment installation:
  - Detailed drawing of the casing pipe (length and levels regarding the formation).
  - Dimensions of the eventual packer.

- Gravel and grouting volume.

– Geological and hydrogeological data, especially observations and performed measurements.

– Elements related to development operations.

All these elements shall be progressively mentioned in the daily report.

In case of erroneous reporting, the Contractor shall be responsible for the resulting defects in the equipment, but shall not have the right to contest the decisions of the Engineer concerning the daily report of the corresponding works.

The daily report shall be permanently maintained on site and delivered upon request to the Engineer.

Technical details stated in the daily report shall be written down by the Contractor on the driller’s log.

The original copy of the driller’s log and the flow tests report shall be delivered to the Engineer at least 48 hours prior to each monthly meeting convened on the site.

704.15 REHABILITATION AND TESTING OF EXISTING BOREHOLES

From time to time, the Contractor shall rehabilitate the existing boreholes as directed by the Engineer. However, the general rehabilitation procedure is as follows:

- Remove all existing equipment from the borehole: Header pipework, cover plate, rising main, cable and pump, such that the borehole is clear of any installed apparatus. All items removed shall be stored safely and in a manner which will facilitate re-use.

- Run a caliper log followed by the full suite of geophysical logs.

- Run plumbness and alignment tests.

- Redevelop the borehole to maximize the yield.

- Undertake pumping test to determine well and aquifer properties, together with ground water sampling.

- Disinfect the borehole.

Some boreholes to be rehabilitated will also require deepening or reaming, and others which are currently unlined are to be cased and screened.

The Engineer will closely monitor the rehabilitation of existing boreholes and at any stage may instruct the Contractor to curtail work if he considers the borehole incapable of sustaining the required long term abstraction for supply.

On completion of rehabilitation, the Engineer will instruct the Contractor to implement one of three possible actions:

- to reinstall the existing pumping equipment to its previous position,
- to cap the well in such a manner as to prevent unauthorized access but to facilitate the measurement of water levels,
- to install in the borehole a new set of pumping equipment.

705 CONTROLS THROUGHOUT THE EXECUTION AND OPERATIONS PRIOR TO WORKS COMMISSIONING

705.1 CONTROLS THROUGHOUT EXECUTION

Throughout works execution, the Contractor shall control at his own expense the following:

a- Plumbness of pipes
b- Grouting
c- Well development
d- Water quality (sand content).

705.1.1 Well plumbness - Plumbness and alignment tests

All wells shall meet the two conditions of plumbness and alignment. In fact, it is not possible to align rigid pipes in a crooked well bore. In the event the bore is straight but considerably inclined from the vertical, pumps may not operate satisfactorily.

It is considered that:

- A deviation of 0.25% (25 cm per 100 m) is minor and seldom causes serious problems.
- Between 0.25% and 0.50%, the deviation becomes serious but not critical if the alignment is maintained.
- Beyond 0.50%, the deviation may cause severe wear on the pump.

Each well bore having a deviation equal or more than 0.50% shall not be automatically commissioned. The Contractor shall correct the straightness in regard with the required conditions.

Method of testing

a) Alignment: Dummy method

- The Contractor shall lower into the well a section of metallic pipe 12 m long.

- The outer diameter of the pipe shall not be more than 1.3 cm smaller than the inside diameter of that part of the casing or hole being tested, when the nominal diameter of the casing is 25 cm or less.

When the nominal diameter of the casing or the well being tested is 30 cm or more, the outer diameter of the dummy shall not be smaller by more than 2.5 cm than the inside diameter of the casing or hole being tested.

Therefore:
for D (nominal diameter of the casing) $\leq$ 25 cm $\Rightarrow$ hole diameter - d (DUMMY) $\leq$ 1.3
for D $\leq$ 30 cm $\Rightarrow$ hole diameter - d (DUMMY) $\leq$ 2.5 cm.

b) Plumbness: Plumbline method

The test for plumbness shall be made with a plumb ring 5 to 6 mm smaller in diameter than the inside diameter of the well or the casing. The hub of the ring must not be solid, the water must pass through it as it is lowered in the well. It must be heavy enough to keep the plumb line taut (ϕ cable = 2 to 3 mm).

The cable shall pass through a guide pulley mounted on a tripod. The center of the pulley shall be exactly 3 meters above the top of the well and it shall be located in a way that the plumb line will come over the center of the well casing (Fig. 4).

First the wire line is reeled out until the plumb is lowered 3 meters. The Contractor shall write down the new position of the cable according to 2 perpendicular diameter axes, marked with 4 reference points on the pipe's edge. The four reference points may constitute the four cardinal points set by a compass.

To facilitate the measurements of the cable position, the Contractor shall use a device like that shown in the enclosed figure (Fig. 4). This device is a thick transparent plastic sheet on which a number of concentric circles are drawn. The larger circle corresponds to the external diameter of the casing. The concentric circles shall have an equidistance of 20 mm.

As the plumb ring is lowered, the plastic sheet is rotated until the slot is oriented in the direction that the wire line tends to drift away from the center. Measurements along the edge of the slot can then be made every 3 meters, to determine the amount of drift as well as the displacement of the plumbing.

Example: Suppose that Pulley C is suspended 3 m above the ground and that plumb line E is in D at the center of the well (see figure 4).

If, after lowering plumb line E 3 meters into the well, cable A has drifted away 1.58 mm from the center (1/16") of waterwell D, the deviation is thus equal to 3.175 mm.

If A is, for example, located at 1/16 inch (1.58 mm) from the center D of the water well, when plumb line E is at a depth of 15 m, then the deviation is equal to (1/16" + 5/16" = 3/8") or 9.5 mm.

Generally, we shall multiply by (n + 1) the cable's displacement value in order to obtain the extent of the deviation at 3 meters depth. It is noteworthy that the principle of the similar triangles allows to calculate the said deviation.

705.1.2 Grouting control

Grouting control shall be carried out by running a temperature log along the grouted portion. The Contractor shall submit to the Engineer the technical specifications of control apparatus.

705.1.3 Development control

Upon the request of the Engineer the Contractor has to control the development when performing the absorption testing.

The borehole shall be filled with water until this latter reaches the casing edge or a lower level agreed upon by the Engineer, then the duration necessary for the water to attain the static level shall be measured. The curves obtained after the development testing must be superposed and shifted from the one obtained before testing. The Contractor shall perform 3 absorption testings. He shall also determine for each well the required water volume to be injected. The origin of this water must be agreed upon by the Engineer.

705.1.4 Sand content control

- The maximal permissible limit of sand content is equal to 10 mg/l.
- The Contractor performs sand content measurements until the sand content is less than 10 mg/L.
- If the Contractor fails to reach this content during development or pump testing, he shall notify the Engineer.

705.2 CONTROLS PRIOR TO WORKS COMMISSIONING

Before commissioning potable waterwells, the following operations shall be performed:

- Measurement of the screening column internal diameter and size.
- Measurement of the water level in the well.
- Control of the well capping.
- Control of the site rehabilitation.
- Control of the well depth.

706 NECESSARY DOCUMENTS

706.1 WORKS REPORT

706.1.1 Daily driller's log

Throughout the works execution, the Contractor shall keep a daily driller's log at the disposal of the Engineer and the Engineer.

All works phases and equipment references as well as all events shall be written down on this document in a chronological order.

706.1.2 Detailed report

Before carrying out the operations prior to works commissioning, the Contractor shall submit to the Engineer a detailed report of the executed works giving a complete description of equipments used on site. In this document, the Contractor rewrites the indications noted on the daily driller's log related to the well.

Moreover, the Contractor shall submit a detailed report on the development and pumping testing works. In particular he shall give a complete description of the equipment used, the date and duration of each mechanical development stage as well as all the remarks concerning the effects and results.

As for chemical treatment, the Contractor indicates the type of the product, its concentration and the quantity used as well as the injection flow, duration and level. He shall also indicate the water volume or flow which has been eventually used to force the product into the aquifer.

As for pumping tests the Contractor shall submit over to the Engineer a report which includes the following:

The description of pumping equipment, in particular the characteristics of the pump (type, power, flows corresponding to certain heads of water, screen depth), the lifting equipment (type, diameter, length) and analytical instruments. The distance and the nature of the disposal point with a corresponding sketch shall be enclosed in this document.

A form for the measurement of water level drawdown, for each pumping test. It includes the date and the time of the pumping flowrate, the measurement of static and dynamic water levels, and all the observations made during pumping (change of rate, water coloration, breakdown, water sampling, pump shut downs...).

A form for the measurement of water recovery after stopping pumping operations, with the date and the time of shut down, according to the indicated frequency. The residual drawdown shall be calculated at each measurement.

Water levels measurement forms; measurements to be taken by means of a piezometer - if available - for drawdown and recovery. Each from shall indicate the distance between the piezometer and the well undergoing pumping as well as the location of the measurement reference point with the corresponding sketch.

706.2 PLANS OF EXECUTED WELLS

The Contractor shall submit to the Engineer the following plans of the executed wells:

706.2.1 Waterwell section (Litholog)

The final waterwell section shall indicate the encountered layers, their depths, and sample descriptions...

Moreover, the section shall include the maximum hydrogeologic indications collected throughout drilling operations, especially the piezometric level of the static aquifer with the date of measurement and the production zones encountered.

706.2.2 Waterwell equipments (Well design)

According to the hydrogeologic section, the Contractor shall perform the waterwell technical section indicating the installed equipment (type, diameters, depths, etc...) particularly:

- Casing columns.
- Annular grouting and cement plugs.
- Screen columns fitted with screens and non perforated pipes, bottom seal.
- Gravel pack.

707 DESCRIPTION OF THE TECHNICAL OFFER

The Contractor shall submit in his offer:

1. A complete list of his drill rigs equipment as well as their technical specifications.

2. A complete list of the equipment and their technical specifications required for:

- Grouting operation (pump...)
- Pumping test (pumps, analytical instruments for measuring water levels, flowrates and time)
- Logs.
- Development (surging, pumping,...)
- Disinfection (pumps, etc...).

3. A complete list of chemical reagents and their technical specifications required for:

- Drilling operation (mud...)
- Grouting operation (cement, sand...)
- Development (polyphosphates)
- Disinfection (disinfecting agents).

4. A description of the drilling methods for each well.

5. A description of the development method for each well.

6. The works implementation schedule for each well.

7. The technical specifications of the non perforated casings of the rising column in each well.

8. The technical specifications of screens for each well.

9. The gravel specifications.

N.B: The Contractor shall choose a Representative who will be able to take the necessary decisions on site and attend the meetings convened on site.